SMITHSONIAN

CONTRIBUTIONS TO KNOWLEDGE.

VOL. XIV.

EVERY MAN IS A VALUABLE MEMBER OF SOCIETY, WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN.—SMITHSON.

CITY OF WASHINGTON:
PUBLISHED BY THE SMITHSONIAN INSTITUTION.
MDCCCLXV.

ADVERTISEMENT.

THIS volume forms the fourteenth of a series, composed of original memoirs on different branches of knowledge, published at the expense, and under the direction, of the Smithsonian Institution. The publication of this series forms part of a general plan adopted for carrying into effect the benevolent intentions of JAMES SMITHSON, Esq., of England. This gentleman left his property in trust to the United States of America, to found, at Washington, an institution which should bear his own name, and have for its objects the "*increase* and *diffusion* of knowledge among men." This trust was accepted by the Government of the United States, and an Act of Congress was passed August 10, 1846, constituting the President and the other principal executive officers of the general government, the Chief Justice of the Supreme Court, the Mayor of Washington, and such other persons as they might elect honorary members, an establishment under the name of the "SMITHSONIAN INSTITUTION FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN." The members and honorary members of this establishment are to hold stated and special meetings for the supervision of the affairs of the Institution, and for the advice and instruction of a Board of Regents, to whom the financial and other affairs are intrusted.

The Board of Regents consists of three members *ex officio* of the establishment, namely, the Vice-President of the United States, the Chief Justice of the Supreme Court, and the Mayor of Washington, together with twelve other members, three of whom are appointed by the Senate from its own body, three by the House of Representatives from its members, and six persons appointed by a joint resolution of both houses. To this Board is given the power of electing a Secretary and other officers, for conducting the active operations of the Institution.

To carry into effect the purposes of the testator, the plan of organization should evidently embrace two objects: one, the increase of knowledge by the addition of new truths to the existing stock; the other, the diffusion of knowledge, thus increased, among men. No restriction is made in favor of any kind of knowledge; and, hence, each branch is entitled to, and should receive, a share of attention.

The Act of Congress, establishing the Institution, directs, as a part of the plan of organization, the formation of a Library, a Museum, and a Gallery of Art, together with provisions for physical research and popular lectures, while it leaves to the Regents the power of adopting such other parts of an organization as they may deem best suited to promote the objects of the bequest.

After much deliberation, the Regents resolved to divide the annual income into two parts—one part to be devoted to the increase and diffusion of knowledge by means of original research and publications—the other part of the income to be applied in accordance with the requirements of the Act of Congress, to the gradual formation of a Library, a Museum, and a Gallery of Art.

The following are the details of the parts of the general plan of organization provisionally adopted at the meeting of the Regents, Dec. 8, 1847.

DETAILS OF THE FIRST PART OF THE PLAN.

I. To increase Knowledge.—*It is proposed to stimulate research, by offering rewards for original memoirs on all subjects of investigation.*

1. The memoirs thus obtained, to be published in a series of volumes, in a quarto form, and entitled "Smithsonian Contributions to Knowledge."

2. No memoir, on subjects of physical science, to be accepted for publication, which does not furnish a positive addition to human knowledge, resting on original research; and all unverified speculations to be rejected.

3. Each memoir presented to the Institution, to be submitted for examination to a commission of persons of reputation for learning in the branch to which the memoir pertains; and to be accepted for publication only in case the report of this commission is favorable.

4. The commission to be chosen by the officers of the Institution, and the name of the author, as far as practicable, concealed, unless a favorable decision be made.

5. The volumes of the memoirs to be exchanged for the Transactions of literary and scientific societies, and copies to be given to all the colleges, and principal libraries, in this country. One part of the remaining copies may be offered for sale; and the other carefully preserved, to form complete sets of the work, to supply the demand from new institutions.

6. An abstract, or popular account, of the contents of these memoirs to be given to the public, through the annual report of the Regents to Congress.

II. To INCREASE KNOWLEDGE.—*It is also proposed to appropriate a portion of the income, annually, to special objects of research, under the direction of suitable persons.*

1. The objects, and the amount appropriated, to be recommended by counsellors of the Institution.

2. Appropriations in different years to different objects; so that, in course of time, each branch of knowledge may receive a share.

3. The results obtained from these appropriations to be published, with the memoirs before mentioned, in the volumes of the Smithsonian Contributions to Knowledge.

4. Examples of objects for which appropriations may be made:—

(1.) System of extended meteorological observations for solving the problem of American storms.

(2.) Explorations in descriptive natural history, and geological, mathematical, and topographical surveys, to collect material for the formation of a Physical Atlas of the United States.

(3.) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity, and of light; chemical analyses of soils and plants; collection and publication of articles of science, accumulated in the offices of Government.

(4.) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5.) Historical researches, and accurate surveys of places celebrated in American history.

(6.) Ethnological researches, particularly with reference to the different races of men in North America; also explorations, and accurate surveys, of the mounds and other remains of the ancient people of our country.

I. To DIFFUSE KNOWLEDGE.—*It is proposed to publish a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge not strictly professional.*

1. Some of these reports may be published annually, others at longer intervals, as the income of the Institution or the changes in the branches of knowledge may indicate.

2. The reports are to be prepared by collaborators, eminent in the different branches of knowledge.

3. Each collaborator to be furnished with the journals and publications, domestic and foreign, necessary to the compilation of his report; to be paid a certain sum for his labors, and to be named on the title-page of the report.

4. The reports to be published in separate parts, so that persons interested in a particular branch, can procure the parts relating to it, without purchasing the whole.

5. These reports may be presented to Congress, for partial distribution, the remaining copies to be given to literary and scientific institutions, and sold to individuals for a moderate price.

The following are some of the subjects which may be embraced in the reports:—

I. PHYSICAL CLASS.

1. Physics, including astronomy, natural philosophy, chemistry, and meteorology.
2. Natural history, including botany, zoology, geology, &c.
3. Agriculture.
4. Application of science to arts.

II. MORAL AND POLITICAL CLASS.

5. Ethnology, including particular history, comparative philology, antiquities, &c.
6. Statistics and political economy.
7. Mental and moral philosophy.
8. A survey of the political events of the world; penal reform, &c.

III. LITERATURE AND THE FINE ARTS.

9. Modern literature.
10. The fine arts, and their application to the useful arts.
11. Bibliography.
12. Obituary notices of distinguished individuals.

II. To diffuse Knowledge.—*It is proposed to publish occasionally separate treatises on subjects of general interest.*

1. These treatises may occasionally consist of valuable memoirs translated from foreign languages, or of articles prepared under the direction of the Institution, or procured by offering premiums for the best exposition of a given subject.

2. The treatises to be submitted to a commission of competent judges, previous to their publication.

DETAILS OF THE SECOND PART OF THE PLAN OF ORGANIZATION.

This part contemplates the formation of a Library, a Museum, and a Gallery of Art.

1. To carry out the plan before described, a library will be required, consisting, 1st, of a complete collection of the transactions and proceedings of all the learned societies of the world; 2d, of the more important current periodical publications, and other works necessary in preparing the periodical reports.

2. The Institution should make special collections, particularly of objects to verify its own publications. Also a collection of instruments of research in all branches of experimental science.

3. With reference to the collection of books, other than those mentioned above, catalogues of all the different libraries in the United States should be procured, in order that the valuable books first purchased may be such as are not to be found elsewhere in the United States.

4. Also catalogues of memoirs, and of books in foreign libraries, and other materials, should be collected, for rendering the Institution a centre of bibliographical knowledge, whence the student may be directed to any work which he may require.

5. It is believed that the collections in natural history will increase by donation, as rapidly as the income of the Institution can make provision for their reception; and, therefore, it will seldom be necessary to purchase any article of this kind.

6. Attempts should be made to procure for the gallery of art, casts of the most celebrated articles of ancient and modern sculpture.

7. The arts may be encouraged by providing a room, free of expense, for the exhibition of the objects of the Art-Union, and other similar societies.

8. A small appropriation should annually be made for models of antiquity, such as those of the remains of ancient temples, &c.

9. The Secretary and his assistants, during the session of Congress, will be required to illustrate new discoveries in science, and to exhibit new objects of art; distinguished individuals should also be invited to give lectures on subjects of general interest.

In accordance with the rules adopted in the programme of organization, each memoir in this volume has been favorably reported on by a Commission appointed for its examination. It is however impossible, in most cases, to verify the statements of an author; and, therefore, neither the Commission nor the Institution can be responsible for more than the general character of a memoir.

The following rules have been adopted for the distribution of the quarto volumes of the Smithsonian Contributions:—

1. They are to be presented to all learned societies which publish Transactions, and give copies of these, in exchange, to the Institution.

2. Also, to all foreign libraries of the first class, provided they give in exchange their catalogues or other publications, or an equivalent from their duplicate volumes.

3. To all the colleges in actual operation in this country, provided they furnish, in return, meteorological observations, catalogues of their libraries and of their students, and all other publications issued by them relative to their organization and history.

4. To all States and Territories, provided there be given, in return, copies of all documents published under their authority.

5. To all incorporated public libraries in this country, not included in any of the foregoing classes, now containing more than 10,000 volumes; and to smaller libraries, where a whole State or large district would be otherwise unsupplied.

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DISCUSSION

OF THE

MAGNETIC AND METEOROLOGICAL OBSERVATIONS

MADE AT THE GIRARD COLLEGE OBSERVATORY, PHILADELPHIA,
IN 1840, 1841, 1842, 1843, 1844, AND 1845.

THIRD SECTION,

COMPRISING PARTS VII, VIII, AND IX. VERTICAL FORCE.

INVESTIGATION OF THE ELEVEN (OR TEN) YEAR PERIOD AND OF THE DISTURBANCES OF THE VERTICAL COMPONENT OF THE MAGNETIC FORCE, AND APPENDIX ON THE MAGNETIC EFFECT OF THE AURORA BOREALIS; WITH AN INVESTIGATION OF THE SOLAR DIURNAL VARIATION, AND OF THE ANNUAL INEQUALITY OF THE VERTICAL FORCE; AND OF THE LUNAR EFFECT ON THE VERTICAL FORCE, THE INCLINATION, AND TOTAL FORCE.

BY

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[ACCEPTED FOR PUBLICATION, AUGUST, 1863.]

PART VII.

INVESTIGATION

OF THE

ELEVEN (OR TEN) YEAR PERIOD, AND OF THE DISTURBANCES OF THE VERTICAL FORCE.

INVESTIGATION

OF THE

ELEVEN (OR TEN) YEAR PERIOD, AND OF THE DISTURBANCES OF THE VERTICAL FORCE.

THE observations of the vertical component of the magnetic force were commenced in June, 1840, and continued, with an exception in January, 1841, without interruption to the last of June, 1845. To keep up the continuity of the series, a daily reading was taken at 2^h 17^m P. M. during the months of January, February, and March, 1843. Up to October, 1843, the observations were bi-hourly, afterwards hourly.

Instruments.—From June, 1840, to the end of the year, the observations were made with a balance vertical force magnetometer of Lloyd's pattern. It was at first mounted in the eastern building of the College, but was removed to the observatory in the latter part of July. While in the College an increase of the readings corresponds to a decrease of vertical force; at the observatory increasing readings denote increasing force. The instrument was made by Robinson, of London; the magnet, the axis of which was mounted as nearly as possible transversely to the magnetic meridian, was 12 inches in length, having at its ends cross wires set in copper rings. For a full description see Dr. Lloyd's account of the Magnetical Observatory of Dublin, and the preface in volume I, of the record of the Philadelphia observations.

In January, 1841, the Lloyd instrument was replaced by a reflecting vertical force magnetometer, made at my suggestion by Mr. J. Saxton. The bar of this instrument was two feet and one inch in length, two inches wide in the middle, one and a half near the ends, tapering to nothing at the ends, and a quarter of an inch thick. The magnet was of steel and hardened as perfectly as the maker could effect. By means of a ball moving on a fine screw, its equilibrium could be changed. The mirror projected outside the box, and the motion of the bar was observed by means of a telescope. At the top of the box was a piece of plate glass through which a thermometer (of Francis' make) could be read. For further particulars see p. vii, of the preface to volume I of the record. For some time (between three and four months) after being put up, the bar lost considerably of its magnetic force, and after being in use four months, a movement of the adjusting ball upon the screw was required for placing the readings again near the middle of the scale. By this adjustment, the sensibility of the apparatus was not interfered with.

The value of a scale division of the Lloyd instrument, expressed in parts of the vertical force, was carefully determined and found to be =0.0000165, both in the

College building and at the observatory. This value being known, I considered that the value of the scale of the new reflecting magnetometer could best be ascertained by comparison with the former. The result of this, continued at intervals, was, that two divisions of the new scale were equivalent to one of the old, or that a change of one division of the reflecting instrument corresponded to a change of vertical force of 0.000033 parts. This was after the instrument had been finally adjusted.

The only disadvantage in the new instrument was the large effect of changes of temperature upon it; by direct observations it was found that a change of 1° (F.) of temperature produced a corresponding change of 13.5 ± 0.25 scale readings, whereas in the Lloyd instrument the corresponding change was but 3.12 scale divisions. We have accordingly for the Lloyd instrument $q=0.0000515$, and for the reflecting instrument $q=0.000446$. The values actually used in the reduction of the observed reading to a standard temperature will be seen further on.

The importance of ascertaining the most correct and suitable coefficients of temperature for the two series of observations, demands a more detailed statement and elaborate discussion of the observations themselves independently of the special trials. Experience has shown that the value for q deduced from the differential intensity observations themselves, with the magnet subject generally to gradual and small changes of temperature, is smaller by a considerable fraction than the value found by direct and special observation during which the temperature changes are necessarily more violent. There is no doubt that in the reduction to a standard temperature that value of q should be used which was obtained while the magnet was under its ordinary influences and condition. The same view is taken by General Sabine, and was also carried out in the discussion of the horizontal component of the magnetic force; for which see the preceding paper (Part IV).

Determination of the Effect of a Change of Temperature on the Readings of the Vertical Force.

(A.) Results of special observations made for determining the temperature coefficient. The correction for temperature of the Lloyd vertical force magnetometer was ascertained by the usual method of vibrating the bar when suspended horizontally, and when alternately heated and cooled artificially. The thermometer was placed with its ball near the axis of the magnet. The changes of the horizontal force magnetometer, while these experiments were going on, were noted and allowed for.

Date. Feb'y, 1841.	Time of 10 oscillations.	Temp. (F.)	Readings of Horz'l force.	Temp. (F.)
9th	$87^s.950$	37°.2	1128.8	25°.6
"	87.900	41.0	1079.3	36.5
"	88.117	94.6	1139.5	36.1
Result	87.990	39.1		
"	88.117	94.6		

$$\text{hence } q=\frac{2}{t'-t}\cdot\frac{\tau'^2-\tau^2}{\tau'^2+\tau^2}=0.0000520$$

which is equivalent to 3.15 scale divisions; in the first reduction of the record 3.12 was used.

Before putting the reflecting vertical force magnetometer in its place in January, 1841, observations were made for its correction for temperature by means of deflections; the result, however, was not satisfactory, owing to the small difference in the deflections at high and low temperatures, and the necessity of keeping the bar at a proper distance from the declinometer to prevent the possibility of a permanent change of magnetism. The weight of the mirror and other fixtures of the bar rendered the method of horizontal oscillations impracticable without their removal, and it was finally decided to determine the value of q by means of a subsidiary instrument kept at a uniform temperature in a separate building, while the vertical force instrument at the observatory was subject to considerable fluctuations of temperature. The subsidiary instrument consisted of a small dipping needle mounted on a knife edge, and rendered horizontal by weighting it. The indications, however, did not prove very satisfactory; 14 scale divisions were indicated as the correction for 1° change in temperature. Subsequently an inclinometer, according to Prof. Lloyd's plan, was mounted as a subsidiary instrument, and observed twice a day with the vertical force instrument at the observatory. The mean values, expressed in scale divisions, thus found between February, 1843, and January, 1844, are as follows:—

13.3 14.3 14.4 12.3 12.2 13.1 and 15.4.

Average value 13.56 ± 0.25. In the first reduction the value 13.5 was used.

(B.) Investigation of the temperature coefficient from the regular series of observations. We will first examine the principal series observed between 1841 (February), and 1845 (June), with the reflecting magnetometer. In February, March, April, and May, 1841, the readings gradually increased and approached the end of the scale, requiring a readjustment of the instrument after May 22. It was supposed that —529 scale divisions would be an approximate correction for referring the observations to the indications of the scale subsequent to May 22, the uninterrupted series of observations commencing with June 1, 1841. The following table contains the *uncorrected* monthly means of the vertical force magnetometer together with the observed mean monthly temperature taken directly from the record. The tabular means for January, February, and March, 1843, when the instrument was read only once a day (at 2^h 17^m P. M.), were obtained as follows: The difference between the daily mean and the mean at 2^h 17^m P. M. was ascertained for each month, from the records of the preceding year (1842) and the following year (1844). The mean correction to the average reading at 2^h 17^m P. M. to refer the same to the mean of the day and month is +18.6, +14.4, and +11.2 scale divisions for the months of January, February, and March, respectively. These corrections have been applied.

TABLE I.—UNCORRECTED MONTHLY MEANS OF VERTICAL FORCE MAGNETOMETER AND CORRESPONDING MEAN MONTHLY TEMPERATURES.

1841.			July . . .	792^{d}.9	77°.5	1844.		
February . .	1059^{d}.0	35°.58	August . .	775.9	75.4	January . .	636^{d}.1	57°.0
March . . .	1236.2	43.96	September .	775.0	74.3	February . .	657.4	59.2
April . . .	1357.4	50.8	October . .	763.8	71.4	March . . .	769.5	67.2
May . . .	1445.6	56.2	November .	725.0	66.8	April . . .	750.1	65.4
June . . .	722.6	74.5	December .	672.8	62.5	May . . .	798.4	69.9
July . . .	810.3	77.6	1843.			June . . .	845.1	73.6
August . .	776.1	75.85	January . .	681.9	64.0	July . . .	913.2	77.2
September .	702.5	71.1	February . .	615.8	57.6	August . .	877.2	75.4
October . .	448.7	54.5	March . . .	555.5	53.8	September .	860.7	71.7
November .	339.8	47.8	April . . .	762.4	71.3	October . .	834.7	71.2
December .	534.1	59.6	May . . .	734.1	70.4	November .	748.2	63.9
1842.			June . . .	784.6	75.9	December .	695.6	60.8
January . .	679.4	67.7	July . . .	800.5	77.4	1845.		
February . .	695.5	65.0	August . .	817.1	77.8	January . .	712.6	62.2
March . . .	668.9	66.8	September .	797.9	74.3	February . .	650.1	56.3
April . . .	671.2	67.4	October . .	749.0	69.6	March . . .	775.7	60.2
May . . .	693.9	69.7	November .	728.0	64.7	April . . .	721.1	65.7
June . . .	718.0	71.9	December .	705.9	62.5	May . . .	688.8	64.1
						June . . .	811.1	74.2

Combining the preceding values by months, we obtain a complete series extending over four years. The first five months are necessarily omitted; the break in the series occurred between the 4th and 5th month.

Uncorrected readings of the vertical force magnetometer. One division of scale =0.000033 parts of the vertical force.

Month.	1841–42.	1842–43.	1843–44.	1844–45.	1841–45.
July	810.3	792.9	800.5	913.2	829.2
August	776.1	775.9	817.1	877.2	811.6
September	702.5	775.0	797.9	860.7	784.0
October	448.7	763.8	749.0	834.7	699.1
November	339.8	725.0	728.0	748.2	635.2
December	534.1	672.8	705.9	695.6	652.1
January	679.4	681.9	636.1	712.6	677.5
February	695.5	615.8	657.4	650.1	654.7
March	668.9	555.5	769.5	675.7	667.4
April	671.2	762.4	750.1	721.1	726.2
May	693.9	734.1	798.4	688.8	728.8
June	718.0	784.6	845.1	811.1	789.6
				Mean	721.3

Corresponding readings of the thermometer (F.).

Month.	1841–42.	1842–43.	1843–44.	1844–45.	1841–45.
July	77°.6	77°.5	77°.4	77°.2	77°.42
August	75.85	75.4	77.8	75.4	76.11
September	71.1	74.3	74.3	71.7	72.85
October	54.5	71.4	69.6	71.2	66.68
November	47.8	66.8	64.7	63.9	60.80
December	59.6	62.5	62.5	60.8	61.35
January	67.7	64.0	57.0	62.2	62.72
February	65.0	57.6	59.2	56.3	59.53
March	66.8	53.8	67.2	60.2	62.00
April	67.4	71.3	65.4	65.7	67.45
May	69.7	70.4	69.9	64.1	68.52
June	71.9	75.9	73.6	74.2	73.90
				Mean	67.45

The last column contains the mean readings. They may be represented by the equation:—

$$V = V_m + \Delta e x + \Delta t y$$

where $x =$ monthly amount of loss of magnetism and effect of secular change.
$y =$ change in magnetometer reading for a change of temperature of 1° F.
$\Delta e =$ epoch—middle epoch. The middle epoch is January 1st.
$\Delta t =$ temperature—mean temperature.
$V_m =$ mean reading of the vertical force magnetometer.
$V =$ any of the monthly means to be represented.

From the 12 conditional equations, we form the normal equations

$$-\ 828.90 = +\ 143.000\ x - \ 85.335\ y$$
$$+\ 4685.73 = -\ 85.335\ x + 443.120\ y$$

whence $x = +\ 0.577$, the monthly change, equal to nearly 7 scale divisions for each year.

And $y = +\ 10.68$ scale divisions, the correction for temperature for 1° F. This is not quite three-fourths of the value found by direct measure.

Second determination of the temperature coefficient by means of alternate combinations by seasons.

The mean values for each season have been directly formed from table No. 1. The value in June, 1845, is necessarily omitted.

				Alternate means.		Differences.		Temp. coefficient.
1841	June to November	633d.3	66°.89					
1841–2	December to May	657.2	66.03	695d.8	69°.88	+38d.6	+3°.85	10d.0
1842	June to November	758.4	72.88	663.8	64.65	—94.6	—8.23	11.5
1842–3	December to May	670.4	63.27	769.0	73.08	+98.6	+9.81	10.1
1843	June to November	779.5	73.28	695.0	63.40	—84.5	—9.88	8.6
1843–4	December to May	719.6	63.53	813.0	72.72	+93.4	+9.19	10.2
1844	June to November	846.5	72.17	705.1	62.54	—141.4	—9.63	14.7
1844–5	December to May	690.6	61.55					
				Mean				10.85
				By preceding method . .				10.68
				Mean, adopted				10.77

We have for the reflecting magnetometer $k = 0.000033$ $\frac{q}{k} = 10.77$, hence $q =$ 0.000355. For comparison we have the corresponding values at Toronto $\frac{q}{k} = 1.80$ and $q = 0.000113$.

The scale value k at Toronto is 0.0000628, nearly twice as large as at Philadelphia. The comparatively large value for q at Philadelphia is most probably due to the large size of the bar which prevents a thorough hardening, a circumstance which undoubtedly also contributes to the difference exhibited by the resulting value of q as found by the direct and indirect methods.

The magnitude of the temperature coefficient requires that the standard temperature should be the mean temperature at all the readings. The average temperature between February, 1841, and June, 1845, is 66°.0, which has been adapted as the standard temperatare to which all the vertical force readings, taken with the reflecting magnetometer, have been referred.

A close examination of the record of the Lloyd balance magnetometer, which was used in June and July, 1840, in the College, and afterwards at the observatory during five months, proved that in point of accuracy it would not compete with the reflecting magnetometer mounted in January, 1841, and continued in use for four years and a half. Owing to some imperfection in the first named instrument, its indications were very unsteady, and at times fitfully changeable; thus in September, October, and December, there are differences in the daily means (deduced from twelve readings and referred to 32° Fahrenheit) of adjacent days of more than 200 scale divisions, and in one instance (October 19–20) amounting even to 256 divisions. In August there is a change of 389 scale divisions in three consecutive days, and in October (17th to the 20th) one of 477 divisions in the means during the same interval. There is besides a large progressive change, showing that the instrument was in a very unstable equilibrium; this change amounted in the first month to over 300 scale divisions. An attempt was also made to deduce a temperature coefficient by comparing mean daily readings of short and specially selected periods of a few days each, with average high and low temperatures, but it failed for want of sufficient uniformity in the indications of the instrument. In such a series the disturbed indications could not be recognized and separated from the regular readings. It was finally concluded to make no use of the observations prior to January, 1841.

Reduction of the Observations, between February, 1841, *and June,* 1845, *to a uniform Temperature.*—A table has been constructed, with the observed temperature as the argument, giving the reduction for difference of temperature from the normal temperature (66° Fahr.); by means of this table each observation has been referred to its corresponding value as the standard temperature. Table No. 2 contains the monthly mean readings for each observing hour; the time is local time, and reckoned from midnight to midnight to 24 hours. The tenths in the record have been omitted, as of no special value, since an error in the recorded temperature of only 0°.1 affects the magnetometer reading by more than a scale division. An increase of scale readings corresponds to a decrease of vertical force, and one division equals 0.000033 parts of the force. Accidental irregularities in the record are especially referred to in foot notes.

The tabular values are directly taken from the manuscript tables containing the single reduced readings and their monthly means.

In the present state of our knowledge regarding the occurrence of the disturbances it is not safe to make any interpolations in the magnetometer record in case of an accidental omission; a rule which has been strictly adhered to.

TABLE II.—RECORD OF THE MONTHLY MEANS OF THE VERTICAL FORCE MAGNETOMETER READINGS FOR EACH OBSERVING HOUR, AND REDUCED TO UNIFORM TEMPERATURE OF 66° FAH.

1841.	0^h	2	4	6	8	10	Noon.	14	16	18	20	22^h	+17^m
February	861	861	860	857	851	846	845	849	847	878	872	867	
March	956	954	949	943	936	933	931	928	941	953	957	957	
April	1004	997	994	988	982	982	981	982	989	997	1006	1009	
May	1033	1031	1030	1021	1012	1009	1008	1008	1012	1022	1037	1043	
June	641	634	631	621	618	618	616	620	627	641	652	653	
July	704	698	686	675	669	666	667	700	684	695	708	707	
August	684	680	673	665	664	655	653	659	663	672	686	690	
September	665	660	657	651	642	633	632	632	637	646	656	662	
October	583	582	578	572	562	559	561	561	569	577	581	582	
November	540	543	540	544	531	528	526	527	532	535	538	540	
December	602	595	595	599	593	598	605	600	606	613	613	613	

Notes to the above table:—February 25th, 6^h 17^m, temperature interpolated, 28°. March 2d, 0^h 17^m, reading 32 minutes late, t=46°.8. March 11th, 22^h 17^m, reading 49^m late, t=41°.7. March 27th, 20^h 17^m, reading 40^m late, t=64°.8. March 29th, 22^h 17^m, reading 43^m late, t=50°.5. April 9th, 16^h 17^m, reading 25^m late, r=920, t=57°.6. April 30th, 0^h 17^m, reading 59^m late, r=805, t=49°.3. May 22d, 14^h 17^m, observations discontinued. Between this date and June 1st the instrument was readjusted, the corrections required to make the readings of the first four months comparable with the continuous series following will be investigated further on. June 29th, 22^h 17^m, reading 38^m late, temperature 81°.8, interpolated. July 22d, 16^h 17^m, temperature 84°.5 interpolated. August 23d, 24th, seven observations were omitted between 20^h 17^m and 8^h 17^m on account of the magnet being fixed by a spider's line which was found attached to the mirror. August 24th, 14^h 17^m, observation rejected, the sun shining on the box. October 4th, 16^h 17^m, sun shining on the needle; October 13th, 22^h 17^m, observation 7^m late; October 28th, 22^h 17^m, observation 67^m late. In December the variations of temperature are unusually large; they seem to demand a greater value of the temperature coefficient. December 8th, 16^h 17^m, observation 8^m late; December 20th, 4^h 17^m, observation 9^m late; December 30th, 18^h 17^m, temperature 69°.0, interpolated.

TABLE II.—*Continued.* VERTICAL FORCE READINGS AT 66° FAH.

1842.	0^h	2	4	6	8	10	Noon.	14	16	18	20	22^h	+17$\frac{1}{2}^m$
January	651	651	663	659	657	651	661	648	660	679	674	674	
February	705	704	714	714	707	698	704	696	699	714	707	701	
March	661	656	662	664	663	662	655	649	655	667	673	666	
April	666	655	659	655	653	654	649	643	645	655	667	670	
May	662	665	657	649	646	647	652	644	647	654	664	665	
June	674	669	663	658	648	643	639	640	636	652	665	663	
July	690	685	675	667	663	656	652	651	656	669	681	684	
August	689	687	685	682	675	668	655	655	665	677	684	686	
September	698	692	696	689	686	677	671	671	673	679	690	698	
October	707	699	703	712	696	709	708	707	707	709	711	706	
November	718	710	723	725	713	715	713	713	716	711	718	718	
December	708	708	714	709	716	711	709	707	705	710	713	713	

Notes to above table:—February 3d, 14^h 17$\frac{1}{2}^m$, the temperature 73°.5 is interpolated. May 9th, 10^h 17$\frac{1}{2}^m$, the temperature 59°.6 is interpolated. June 6th, 0^h 17$\frac{1}{2}^m$, 2^h 17$\frac{1}{2}^m$, and 18^h 17$\frac{1}{2}^m$, the temperatures 70°.4, 71°.0, and 74°.4 respectively, were interpolated. August 3d, 12^h 17$\frac{1}{2}^m$; 5th, 22^h 17$\frac{1}{2}^m$; 6th, 10^h 17$\frac{1}{2}^m$, and 31st, 14^h 17$\frac{1}{2}^m$, the temperatures 69°.0, 73°.7, 76°.0, and 67°.6 respectively, were interpolated. September 1st, 22^h 17$\frac{1}{2}^m$, the temperature 77°.0 is interpolated. October 8th, 2^h 17$\frac{1}{2}^m$; 21st, 10^h 17$\frac{1}{2}^m$, and 28th, 6^h 17$\frac{1}{2}^m$, the temperatures 66°.1, 68°.1, and 70°.8 respectively, were interpolated. November 3d, 14^h 17$\frac{1}{2}^m$; and 16th, 6^h 17$\frac{1}{2}^m$, the observations are 6^m and 7^m late.

TABLE II.—*Continued.* VERTICAL FORCE READINGS AT 66° FAH.

1843.	0h	2	4	6	8	10	Noon.	14 +17m	16	18	20	22h	+23½m
January								685					
February								692					
March								676					
April	715	713	713	712	708	702	705	687	697	696	706	709	
May	698	697	695	690	683	680	677	666	678	679	697	690	
June	696	691	693	690	677	669	664	660	659	671	681	690	
July	692	693	693	689	681	673	664	660	660	667	678	686	
August	702	703	707	705	695	682	670	672	672	682	694	698	
September	722	720	721	716	707	705	694	693	694	701	710	708	
October	714	708	714	717	704	703	702	703	704	714	719	714	
November	740	737	744	744	743	740	734	735	746	750	748	745	
December	749	737	740	740	739	728	724	738	755	759	762	754	

Additional odd hours observed.

1843.	1h	3	5	7	9	11	13	15	17	19	21	23h	+23½m
October	710	709	718	712	704	700	701	702	709	717	715	717	
November	737	740	745	747	742	735	731	741	750	751	746	747	
December	744	738	742	743	738	720	726	747	755	763	756	757	

Notes to the above table:—January 4th, February 1st, and March 24th, observations 7m, 7½m, and 20m late, respectively. In April seven readings were supplied by the observers, also one in May and one in June. July 14th, 0h 23½m, observation 6m late. August 10th, 16h 23½m, observation supplied by observer. August 29th, 0h 23½m, observation 12m late. September 20th, 0h 23½m, temperature supplied by observer. November, six readings supplied by observers. December 1st, 4h 23½m; December 9th, 1h 23½m; December 12th, 21h 23½m, and December 22d, 5h 23½m, observations 5m, 6m, 15m, and 8m late, respectively. December 19th, 2h 23½m, a printing error of 200 scale divisions was corrected. December 30th, 9h 23½m, reading supplied by observer.

TABLE II.—*Continued.* VERTICAL FORCE READINGS AT 66° FAH.

1844.	0h	1	2	3	4	5	6	7	8	9	10	11h	+23½m
January	735	733	731	731	733	736	733	733	731	730	726	717	
February	736	731	729	730	733	732	733	734	727	725	727	720	
March	763	758	758	759	760	762	763	760	755	759	761	762	
April	7[illegible]6	765	763	765	766	765	763	759	752	751	746	740	
May	772	769	766	768	767	764	760	754	749	747	747	744	
June	778	776	772	772	771	768	765	7[illegible]0	752	750	749	747	
July	809	807	803	802	801	798	794	789	780	779	778	777	
August	794	792	788	787	785	783	780	774	768	765	761	759	
September	815	813	811	808	809	807	805	802	796	793	788	783	
October	779	776	773	776	778	780	781	782	775	774	775	771	
November	775	771	768	769	772	772	771	773	768	772	772	767	
December	756	752	753	754	756	757	756	750	752	752	754	749	

1844.	Noon.	13	14	15	16	17	18	19	20	21	22	23h	+23½m
January	717	713	717	724	732	740	743	745	747	746	744	745	
February	716	719	720	723	731	735	742	743	743	739	738	737	
March	758	751	752	755	752	751	751	749	750	751	759	762	
April	739	735	738	744	750	754	758	764	764	762	765	766	
May	744	740	740	744	746	748	753	762	765	766	768	772	
June	746	745	748	752	754	757	765	772	775	774	775	778	
July	776	775	772	778	780	787	795	801	804	804	806	809	
August	756	756	752	765	767	769	777	787	788	788	790	793	
September	779	777	766	791	790	793	804	810	809	810	812	815	
October	769	767	771	778	787	789	792	790	786	786	782	782	
November	766	763	761	758	774	779	777	778	774	770	769	772	
December	745	739	740	735	750	756	754	753	753	750	751	754	

Notes to preceding table:—January 2d, $10^h\ 23\frac{1}{2}^m$, temperature observation 30^m late. January 8th, $10^h\ 23\frac{1}{2}^m$, instrument disturbed. January 15th, $3^h\ 23\frac{1}{2}^m$, temperature $56^\circ.3$ interpolated. February 6th, $4^h\ 23\frac{1}{2}^m$, and 13th, $9^h\ 23\frac{1}{2}^m$, temperature observation 15^m and 20^m late, respectively. April 11th, $0^h\ 23\frac{1}{2}^m$ and $1^h\ 23\frac{1}{2}^m$, readings supplied by observer. July 13th, $12^h\ 23\frac{1}{2}^m$, observation 36^m late. August 26th and 27th, thirteen readings supplied by observers. October 1st, $22^h\ 23\frac{1}{2}^m$, observation 8^m late.

TABLE II.—*Continued.* VERTICAL FORCE READINGS AT 66° FAH.

1845.	0^h	1	2	3	4	5	6	7	8	9	10	11^h	$+23\frac{1}{2}^m$
January	754	748	749	751	752	756	762	767	760	758	753	751	
February	761	756	753	757	759	760	763	764	756	756	752	749	
March	749	743	739	742	745	744	745	743	735	733	732	729	
April	732	727	726	728	729	727	725	724	719	718	718	717	
May	722	720	718	721	718	717	715	711	707	704	702	701	
June	733	731	729	729	729	727	726	722	717	715	715	711	

1845.	Noon.	13	14	15	16	17	18	19	20	21	22	23^h	$+23\frac{1}{2}^m$
January	752	748	749	739	754	759	756	753	748	746	746	753	
February	747	741	740	739	753	759	761	761	758	753	752	756	
March	730	729	713	731	737	741	745	746	740	740	739	742	
April	716	713	715	724	726	723	732	737	735	729	726	728	
May	699	698	680	700	704	704	712	719	719	717	719	720	
June	711	711	711	714	713	715	722	730	733	731	731	732	

Notes to above table:—April 27th, $4^h\ 23\frac{1}{2}^m$, reading supplied by observer. April 14th, $2^h\ 23\frac{1}{2}^m$, observation 12^m late. April 22d, 23d, and 28th, $14^h\ 23\frac{1}{2}^m$; also April 22d, $15^h\ 23\frac{1}{2}^m$, readings supplied by observer. April 22d, $16^h\ 23\frac{1}{2}^m$, temperature supplied by observer. May 2d, $14^h\ 23\frac{1}{2}^m$, reading supplied by observer. May 12th, $4^h\ 23\frac{1}{2}^m$, 9^m late. June 6th, $5^h\ 23\frac{1}{2}^m$, and 28th, $1^h\ 23\frac{1}{2}^m$, observations 13^m and 9^m late, respectively. June 12th, $0^h\ 23\frac{1}{2}^m$ and $1^h\ 23\frac{1}{2}^m$, readings supplied by observer.

TABLE III.—MEAN MONTHLY READINGS OF THE VERTICAL FORCE REDUCED TO THE TEMPERATURE OF 66° FAH.

	1841.	1842.	1843.	1844.	1845.
January		661	699	733	752
February	858	705	702	731	754
March	945	661	684	757	738
April	993	656	705	756	725
May	1022	654	686	756	710
June	631	654	678	762	722
July	688	669	678	792	
August	670	676	690	776	
September	648	685	708	799	
October	572	706	710	779	
November	535	716	742	770	
December	603	710	744	751	
Mean		679	702	763	

The monthly mean for January, February, and March, 1843, was obtained by adding 14, 10, and 8 divisions to the readings at $14^h\ 7^m$ respectively; these corrections were found by comparisons in 1842 and 1844.

Corrections for progressive and irregular changes.—The difficulty of fully eliminating all effects of changes of temperature, and adjustment, particularly during the first year (1841), demanded the application of a secondary process analogous to that used in the reduction of the horizontal force for progressive change. The progressive change in the readings of the vertical force is less decided and more fluctuating than in the horizontal force. Half monthly means, and in special cases, means of even less periods of time, have been taken and were compared with the monthly mean, the differences were applied either progressively (increasing or diminishing) or as constants, as the case seemed to demand.

Seventeen months required no such correction, and in many months it was applied very sparingly.

The process leaves the diurnal variation, relatively, undisturbed, and prepares the series for the application of Peirce's Criterion for the recognition of the disturbances. The individual figures thus corrected were inserted in blue ink in the manuscript tables.

Recognition and separation of the larger disturbances.—Peirce's Criterion for the recognition of the disturbances was applied to the observations extending over four years, and commencing with July, 1841, in the following order: July 0^h, August 2^h, September 4^h, October 6^h, November 8^h, December 10^h, January (1842) 12^h, etc. The odd hours were selected from July, 1844, to the close of the series, thus July 1^h, August 3^h, September 5^h, etc. The following limits of separation, in scale divisions, have been found for each year:—

July, 1841 —	June,	1842,	limit,	52
" 1842 —	"	1843,	"	46
" 1843 —	"	1844,	"	40
" 1844 —	"	1845,	"	33
			Average limit,	43

As this limit would only separate 1 in every 34 observations, and would not furnish a sufficient number of disturbances to investigate their laws to advantage, it was necessary to contract the above limit, and 30 scale divisions were finally selected. There can be no doubt that the limiting number as found by the use of the criterion is too high, owing to the unavoidable presence of irregularities ascribable to imperfection in the corrections for temperature in some cases, and in others due to apparently fitful changes in the instrument. 30 scale divisions =0.00099 parts of the vertical force =0.0127[1] in absolute measure, adopted as limit of deviation of any observation from its corresponding mean monthly value for the same hour, will furnish an average value for the ratio of the number of disturbances to the whole number of observations. The ratio of a disturbance to the whole force is also nearly the same for the horizontal and vertical component.

All deviations over 30 divisions from the mean were marked, and a new mean was taken, the hourly observations were again compared with this new mean, and

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[1] The vertical force, in absolute measure, is on the average, between 1841 and 1845, equal to 12.84 (English units), as stated in a subsequent number of this discussion.

the process was repeated, if necessary, until all deviations above 30 had been separated; the final hourly means for each month, thus found and known as the "normals," are given in the following tables.

TABLE IV.—BI-HOURLY NORMALS OF THE VERTICAL COMPONENT OF THE MAGNETIC FORCE IN 1841.

One division of the scale =0.000033 parts of the vertical force. Increasing numbers denote decrease of force. The observations are made 17^m after the full hours.

1841.	0^h	2	4	6	8	10	Noon.	14	16	18	20	22^h
February	664	654	662	656	654	650	644	648	647	673	668	665
March	670	661	661	655	651	645	643	646	656	665	666	673
April	671	662	658	653	645	646	646	649	656	666	670	676
May	669	665	660	654	647	649	644	646	650	660	674	679
June	646	631	622	617	624	616	603	624	635	650	653	657
July	703	697	687	671	667	664	665	676	680	698	708	706
August	686	680	676	664	662	652	653	662	666	676	689	691
September	653	655	646	647	637	631	627	628	634	645	653	660
October	579	578	573	568	558	556	561	562	571	577	581	583
November	532	537	538	533	526	523	520	521	526	529	531	538
December	597	591	590	606	592	598	605	597	607	610	605	604

The normals for February, March, April, and May, have been diminished by 198, 278, 333, and 361 scale divisions respectively; the uncorrected monthly means are 856, 936, 991, and 1019, which can be exactly represented by the expression $r = 966 + 54.4\ \Delta t - 12.8\ \Delta t^2$, where $r =$ monthly reading and t, expressed in units of a month, counts from April 1 as the epoch. It shows that the monthly increase is uniformly retarded. The mean reading from the four succeeding months is 658, the corrections to February, March, April, and May, as applied, will produce the same mean.

The rapid change in the monthly means for some adjacent months makes a small correction necessary to the monthly means, viz: of plus one scale division to the February, March, and December means of the hours 0, 2, and 4, and to the September and October means at the hours 18, 20, and 22; of minus one scale division to the February, March, and December means at the hours 18, 20, and 22, and to the September and October means at the hours 0, 2, and 4. This small correction is included in the above normals.

TABLE IV.—*Continued.* BI-HOURLY NORMALS OF THE VERTICAL COMPONENT IN 1842.

The observations are made $17\frac{1}{2}^m$ after the full hours.

1842.	0^h	2	4	6	8	10	Noon.	14	16	18	20	22^h
January	(658)	642	656	649	656	653	664	650	663	675	670	663
February	706	701	713	721	699	698	709	692	698	712	723	710
March	655	643	654	663	657	661	651	650	657	668	673	665
April	668	658	655	655	656	654	657	651	650	660	672	672
May	673	670	661	644	646	647	651	644	645	656	668	670
June	674	669	664	658	647	642	635	639	635	653	671	668
July	683	672	664	659	657	650	643	643	647	663	677	682
August	689	689	683	682	679	672	652	659	669	679	688	688
September	692	686	689	690	681	671	671	673	672	679	687	693
October	706	698	702	714	695	708	707	706	706	708	710	709
November	717	713	723	725	712	715	711	713	716	712	718	718
December	713	707	709	706	715	711	709	707	706	711	713	713

In January at 0^{h} the final mean is 637 which differs so much from the standard value at this hour that it was preferred to substitute the mean of the month (658) as a close approximation.

TABLE IV.—*Continued.* BI-HOURLY NORMALS OF THE VERTICAL COMPONENT IN 1843.

The observations are made $23\frac{1}{2}^{m}$ after the full hours.

1843.	0^{h}	2	4	6	8	10	Noon.	14	16	18	20	22^{h}
January								690				
February								697				
March								686				
April	715	712	717	716	708	702	709	700	696	696	710	709
May	698	699	695	690	682	680	677	668	677	685	691	695
June	698	691	693	687	677	668	663	658	659	669	681	689
July	691	692	692	686	679	672	662	658	659	666	677	685
August	703	703	708	706	698	683	669	671	672	682	695	699
September	721	719	721	716	707	706	693	692	692	703	714	710
October	714	707	712	717	706	703	702	703	704	714	719	714
November	742	745	745	744	742	737	735	731	746	749	749	746
December	752	733	740	740	740	729	727	743	758	767	764	754

Normals at additional odd hours.

1843.	1^{h}	3	5	7	9	11	13	15	17	19	21	23^{h}
October	710	713	714	714	704	701	700	701	709	717	715	717
November	740	743	744	748	739	729	731	738	749	751	747	748
December	744	742	742	743	740	720	729	749	760	763	757	757

TABLE IV.—*Continued.* HOURLY NORMALS OF THE VERTICAL COMPONENT IN 1844.

The observations were made $23\frac{1}{2}^{m}$ after the full hours.

1844.	0^{h}	1	2	3	4	5	6	7	8	9	10	11^{h}
January	733	739	730	728	732	733	732	732	730	725	720	713
February	734	729	725	726	729	728	729	730	723	724	722	717
March	768	761	763	760	764	762	765	762	758	761	762	764
April	776	773	771	765	766	765	759	755	749	749	744	740
May	772	769	766	768	767	764	760	754	749	747	747	744
June	776	772	767	768	767	764	760	755	747	745	744	744
July	816	811	804	806	805	802	798	793	784	783	782	780
August	794	790	786	781	783	777	776	769	763	760	756	754
September	816	815	813	812	811	810	809	805	798	795	790	785
October	775	771	769	773	776	779	780	780	774	773	773	770
November	775	772	768	769	772	771	770	773	768	772	772	767
December	754	753	754	755	757	756	755	758	749	751	750	746

1844.	Noon.	13	14	15	16	17	18	19	20	21	22	23^{h}
January	715	708	715	724	737	740	741	743	744	745	744	744
February	718	716	716	720	727	731	738	739	740	737	735	733
March	762	753	758	760	754	757	753	754	752	753	763	764
April	737	733	737	741	745	744	756	767	768	765	767	775
May	744	740	747	744	746	748	754	763	766	766	768	772
June	742	739	744	747	749	754	760	769	771	770	771	775
July	780	776	773	781	783	791	799	805	808	809	811	816
August	750	750	746	759	764	771	778	789	790	789	792	794
September	780	779	772	794	793	795	806	813	812	812	814	817
October	769	766	773	777	786	788	791	789	785	785	781	781
November	766	763	762	765	774	779	777	778	774	770	769	772
December	743	733	736	724	748	757	755	751	751	748	750	750

TABLE IV.—*Continued.* HOURLY NORMALS OF THE VERTICAL COMPONENT IN 1845.

The observations are made $23\frac{1}{2}^m$ after the full hours.

1845.	0^h	1	2	3	4	5	6	7	8	9	10	11^h	Noon.	13	14	15	16	17	18	19	20	21	22	23^h
January	754	747	747	752	752	757	763	767	760	758	753	752	751	748	749	742	753	760	756	753	749	746	747	754
February	760	756	752	757	759	760	763	764	756	756	752	749	747	741	740	744	753	759	761	761	758	753	752	756
March	749	741	736	742	746	748	749	746	736	733	732	729	729	729	713	734	740	747	751	746	741	740	739	743
April	732	727	728	729	728	727	725	721	718	715	717	717	716	713	717	720	724	724	732	737	736	729	726	727
May	720	718	717	719	716	715	713	709	705	702	701	699	697	696	701	698	702	705	710	720	718	717	718	719
June	733	731	729	730	729	728	726	722	717	715	715	711	711	711	713	714	713	714	722	730	735	731	731	733

TABLE V.—NUMBER OF OBSERVATIONS AND LARGER DISTURBANCES IN EACH MONTH.

	1841.		1842.		1843.		1844.		1845.	
	Obs.	Dis.	Obs	Dis.	Obs.	Dis.	Obs.	Dis.	Obs.	Dis.
January . . .			300	76	26	5	646	81	648	17
February . . .	288	49	284	86	24	3	600	33	576	5
March	321	64	322	36	27	12	624	106	624	68
April	304	46	306	51	300	50	624	83	624	24
May	223	16	293	47	324	36	648	8	648	28
June	310	91	310	37	312	16	600	52	600	9
July	323	64	305	24	312	4	648	45		
August . . .	304	21	318	34	324	10	648	94		
September . .	307	40	303	57	312	20	600	14		
October . . .	308	28	310	12	624	25	648	20		
November . .	312	37	312	13	624	79	624	10		
December . .	323	84	319	15	624	65	624	47		
Sum . . .	3323	540	3682	488	3833	325	7534	593	3720	151
Ratio . . .	1 dis. in 6.2 obs.		1 dis. in 7.5 obs.		1 dis. in 11.8 obs.		1 dis. in 12.7 obs.		1 dis. in 24.6 obs.	

Total number of observations used,	22092
" " larger disturbances,	2097
Ratio of disturbances to observations,	1 to 10.5

Investigation of the eleven year (also called ten year) period in the inequality of the amplitude of the Diurnal Variation of the Vertical Force.—The preceding monthly means of the bi-hourly and hourly normals were rearranged in four groups of one year each, necessarily omitting the first five months; the annual means have for their mean epoch, January, as the monthly means were arranged from July to July.

The means for the year 1842–43 depend on nine months only, to refer them to the mean of twelve months, the differences for every observing hour, between the same nine months and twelve months for the preceding and following year, were made out and the mean correction, giving the weight two to the following year, as indicated by the readings taken at the hour 14, was applied to the values of 1842–43.

	From 9 months.	Correction.	Annual means		From 9 months.	Correction.	Annual means
0h	701	+3	704	Noon	682	+8	690
2	696	+3	699	14	681	+6	687
4	697	+5	702	16	683	+7	690
6	697	+6	703	18	689	+7	696
8	690	+6	696	20	697	+5	702
10	686	+7	693	22	700	+5	705

The normals for 1843–44 at the even hours are complete, at the odd hours they extend only over nine months. To refer the latter to twelve months, the difference between the means of the same nine months and the annual mean at the even hours was made out and applied as a correction to the means of the odd hours; the correction thus applied is the mean difference as deduced from the preceding and following even hour.

	Means of 9 months.	Correction.	Annual means.		Means of 9 months.	Correction.	Annual means.
1h	749	—11	738	13h	728	—14	714
3	746	—10	736	15	726	—16	720
5	746	—11	735	17	744	—16	728
7	744	—11	733	19	752	—15	737
9	737	—12	725	21	751	—14	737
11	730	—13	717	23	754	—13	741

TABLE VI.—ANNUAL MEANS OF THE BI-HOURLY AND HOURLY NORMAL VALUES OF THE REGULAR SOLAR-DIURNAL VARIATION OF THE VERTICAL FORCE.

The numbers are expressed in scale divisions, increasing values indicate decrease of force. The minutes at the head of each column are to be added to the hour given in the first column. Each year commences with the month of July. The time is local Philadelphia time counted from midnight to midnight.

Hour.	1841–42. $+17\frac{1}{4}^{m}$	1842–43. $+20\frac{1}{2}^{m}$	1843–44. $+23\frac{1}{2}^{m}$	1844–45. $+23\frac{1}{2}^{m}$
0 A. M.	650	704	740	765
1 "			738	761
2 "	643	699	735	759
3 "			736	760
4 "	643	702	737	761
5 "			735	761
6 "	640	703	734	761
7 "			733	759
8 "	634	696	727	752
9 "			725	751
10 "	632	693	722	749
11 "			717	747
12 P. M.	633	690	717	745
13 "			714	742
14 "	631	687	718	741
15 "			720	746
16 "	636	690	724	753
17 "			728	758
18 "	647	696	732	762
19 "			737	764
20 "	654	702	738	763
21 "			737	761
22 "	652	705	738	761
23 "			741	764
Means	641	697	730	756

The following formulæ of the mean diurnal variation of the vertical force were deduced from the above tabular values. The angle θ counts from midnight at the rate of 15° an hour.

$$\begin{array}{ll}
\text{1841–42} & V = 641^d + 10^d.4\ sin\ (\theta + 106^\circ\ 40') + 3^d.1\ sin\ (2\theta + 198^\circ\ 25') + 1^d.7\ sin\ (3\theta + 250^\circ) \\
\text{1842–43} & V = 697 + 7.6\ sin\ (\theta + 69\ \ 17\ ) + 2.9\ sin\ (2\theta + 196\ \ 48\ ) + 1.3\ sin\ (3\theta + 195\ ) \\
\text{1843–44} & V = 730 + 11.0\ sin\ (\theta + 79\ \ 54\ ) + 3.4\ sin\ (2\theta + 226\ \ 29\ ) + 0.6\ sin\ (3\theta + 45\ ) \\
\text{1844–45} & V = 756 + 9.2\ sin\ (\theta + 83\ \ 40\ ) + 4.3\ sin\ (2\theta + 233\ \ 41\ ) + 1.1\ sin\ (3\theta + 1\ )
\end{array}$$

In the construction of the equation for 1843–44 weighted normals were used, those of the even hours have the weight 4, of the odd hours the weight 3.

To show the degree of accordance in the expressions when deduced from the even and odd hours separately, the resulting equations for the last year are added:—

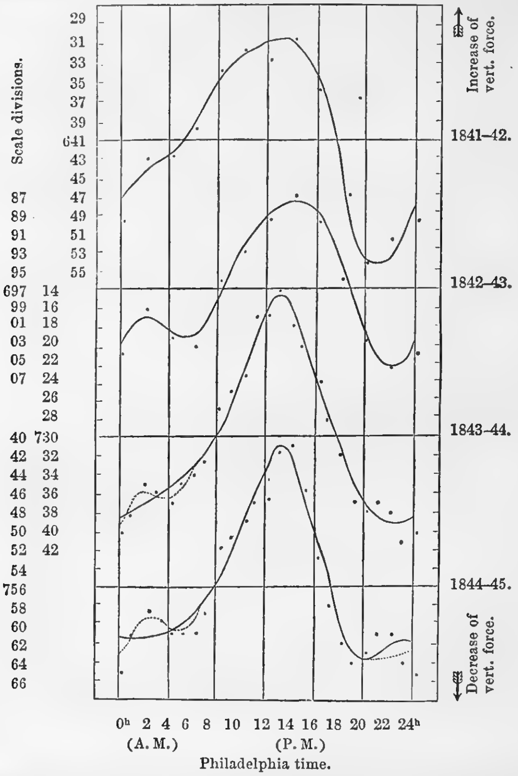
$$\begin{array}{ll}
\text{Even hours:} & V = 756 + 9.32\ sin\ (\theta + 84^\circ 45') + 4.07\ sin\ (2\theta + 235^\circ 17') + 1.2\ sin\ (3\theta + 353^\circ) \\
\text{Odd \ \ “} & V = 756 + 8.99\ sin\ (\theta + 82\ \ 36\ ) + 4.52\ sin\ (2\theta + 232\ \ 05) + 1.0\ sin\ (3\theta + 10\ )
\end{array}$$

The observed and computed values compare as follows. The differences, observed less computed, are expressed in scale divisions:—

Hour.	1841–42.	1842–43.	1843–44.	1844–45.	
0	+2	+2	+1	+3	17¼, 20½, 23½, and 23½ minutes are to be added to the full hours for the four years respectively.
2	−1	−1	−2	−2	
4	0	+1	+1	0	
6	+1	+1	+1	+2	
8	0	−1	−2	−3	
10	0	+1	+1	0	
Noon	+1	+1	+1	+2	
14	−1	−1	+1	−2	
16	0	+1	0	+1	
18	+1	+1	0	+1	
20	0	0	+1	−1	
22	−1	0	−1	−1	

The graphical representation of the observed and computed values exhibits a maximum of the vertical force between 1 and 2 P. M., and a minimum of force between 8½ and 10½ A. M.; the diagrams also show a tendency of a secondary maximum about two hours after midnight followed by a secondary minimum about two hours later, with a range probably less than two scale divisions (0.000066 parts of the force, or 0.00085 in absolute measure). This small nocturnal inequality is only exhibited by one of the formulæ, in 1842–43, when it has its greatest value; in the preceding year there is but a faint trace of it, in the two succeeding years it is indicated in the diagram by dashes. The average diurnal range is nearly 22 scale divisions (0.00073 parts of the vertical force, or 0.00932 in absolute measure).

INEQUALITY IN THE DIURNAL VARIATION OF THE VERTICAL FORCE.



EPOCH AND AMOUNT OF THE PRINCIPAL MAXIMUM AND MINIMUM AND AMPLITUDE OF THE DIURNAL INEQUALITY.

Year.	Maximum.		Minimum.		Amplitude.		
	Reading.	Epoch.	Reading.	Epoch.	Scale div.	In parts of v. f.	In absol. meas.
1841–42	$630^d.9$	$13^h\ 15^m$	$654^d.5$	$20^h\ 50^m$	$23^d.6$	0.00078	0.01000
1842–43	687.8	14 25	705.1	22 10	17.3	0.00057	0.00733
1843–44	715.1	13 00	739.3	23 00	24.2	0.00080	0.01025
1844–45	741.8	13 10	763.8	20 30	22.0	0.00073	0.00932
Mean		13½		21½	21.8		

The epochs are given to the nearest quarter of an hour.

If we compare the Philadelphia and Toronto curves, we find a general correspondence in their form, the early morning secondary inflection being well exhibited at Toronto; the epochs of the two curves, however, are shifted by nearly three hours, thus: at Toronto principal maximum at 5 P. M., at Philadelphia 1½ P. M.;

principal minimum at Toronto 10 A. M., at Philadelphia 9½ A. M.; the epochs of the early morning inflection are also about 3½ hours later at Toronto. The curves exhibit also a difference in the amplitude, at Toronto, Vol. III, the diurnal range is 0.00019 parts, whereas at Philadelphia we found it much larger.

The special study of the solar diurnal variation of the vertical force is reserved for Part VIII.

The minimum diurnal range occurred in 1842–43, on the average, therefore, we may assume May, 1843, as the epoch of the minimum range in the eleven (or ten) year period, resulting from the discussion of the declination, horizontal and vertical force observations.

To facilitate the comparison with similar expressions at other stations, the preceding equations of the diurnal variation are also presented, expressed in parts of the vertical force. The angles have been changed 180° to reverse the order of progression of the scale numbers.

1841–42 $V = +0.00034 \sin(\theta + 286^\circ 40') + 0.00010 \sin(2\theta + 18^\circ 25') + 0.00006 \sin(3\theta + 70^\circ)$
1842–43 $V = +0.00025 \sin(\theta + 249\ \ 17) + 0.00010 \sin(2\theta + 16\ \ 48) + 0.00004 \sin(3\theta + 15\ )$
1843–44 $V = +0.00036 \sin(\theta + 259\ \ 54) + 0.00011 \sin(2\theta + 46\ \ 29) + 0.00002 \sin(3\theta + 225)$
1844–45 $V = +0.00030 \sin(\theta + 263\ \ 40) + 0.00014 \sin(2\theta + 53\ \ 41) + 0.00004 \sin(3\theta + 181)$

The constant terms and numerical coefficients when expressed in absolute measure (English units) are as follows:—

		Term involving		
	Y	θ	2θ	3θ
1841–42	12.85	0.00441	0.00131	0.00072
1842–43	12.84	0.00322	0.00123	0.00055
1843–44	12.83	0.00468	0.00144	0.00025
1844–45	12.83	0.00388	0.00172	0.00047

The angle θ counts from midnight.

Investigation of the Eleven (or ten) Year Inequality in the Disturbances, and General Analysis of the Disturbances of the Vertical Force.—By means of Table V, a new table was formed of the number of disturbances in each month for the years 1841–42, 1842–43, 1843–44, 1844–45, commencing with July, and all referred to a uniform series of bi-hourly observations; the numbers for and after October, 1843, were halved. The number of disturbances for January, February, and March, 1843, are the means between the same months in the preceding and following year. The annual means of this Table (VII) are as follows:—

	Mean number of Disturbances.
In 1841–42	51
" 1842–43	34
" 1843–44	25
" 1844–45	16

This seems to indicate the end of the year 1844 as the epoch of the minimum number of disturbances in the eleven year period, taking the numbers collectively for declination, horizontal and vertical force, the minimum probably took place in the spring of 1844.

If we take the monthly aggregate amount of the disturbances, all referred to a uniform series of bi-hourly observations, and form a table of these values for each year (Table VIII), the mean aggregate amount for each year is as follows:—

	Mean amount of disturbances.
In 1841–42	2306 div.
" 1842–43	1521
" 1843–44	959
" 1844–45	636

This again points to the end of the year 1844 for the epoch of the minimum amount of disturbances, and considering the three elements, declination, horizontal and vertical force, the spring of 1844 might be assumed as the time of the minimum magnitude of the magnetic disturbances.

Altogether, the inequalities in the diurnal amplitude and in the number and magnitude of the disturbances of the magnetic elements, as observed at Philadelphia, fix the end of the year 1843, or the beginning of 1844, as the epoch of the minimum of the eleven (or ten) year inequality.

We now proceed with the analysis of the disturbances, their diurnal and annual inequality in number and amount, and for increasing and decreasing values.

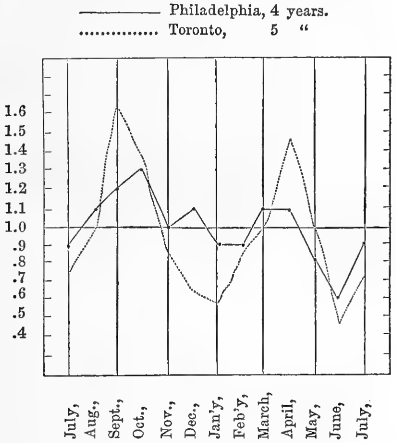
Annual Inequality in the number of Disturbances.—The numbers for each month have been referred to a uniform series of bi-hourly observations as explained above. The ratios of the monthly means to the annual means is given, and also, for comparison, similar ratios found for the horizontal force and declination.

TABLE VII.—ANNUAL INEQUALITY IN THE NUMBER OF DISTURBANCES.

	1841–1842.	1842–1843.	1843–1844.	1844–1845.	Means from four years.	Vert. force ratio.	Hor. force ratio.	Declination ratio.	Mean ratio Vert. force hor. force and declination.	Mean ratio Hor. force and declination.
July	64	24	4	22	28	0.9	1.1	0.9	1.0	0.9
August	21	34	10	47	28	0.9	0.9	1.6	1.3	1.1
September	40	57	20	7	31	1.0	1.4	1.4	1.4	1.2
October	28	12	12	10	15	0.5	1.4	2.1	1.7	1.3
November	37	13	40	5	24	0.8	1.0	1.1	1.1	1.0
December	84	15	33	23	39	1.3	1.0	1.0	1.0	1.1
January	76	58	40	9	46	1.5	0.6	0.8	0.7	0.9
February	86	51	16	3	39	1.3	1.0	0.5	0.7	0.9
March	36	44	53	34	42	1.4	1.1	0.7	0.9	1.1
April	51	50	42	12	39	1.3	1.1	0.9	1.0	1.1
May	47	36	4	14	25	0.8	1.0	0.6	0.8	0.8
June	37	16	26	4	21	0.7	0.6	0.5	0.6	0.6
Mean	51	34	25	16	31					

The months of maximum disturbance are March and September (the high value in January and the low one in October appear anomalous, and would no doubt disappear in a longer series of observations). The minimum occurs in June; there is no well expressed second minimum. The horizontal force and declination ratios, as well as the ratios of the three elements at Toronto, give the maximum number of disturbances at the equinoxes, and the minimum number at the solstices, and as the winter solstice minimum only is wanting in the Philadelphia vertical force ratios, it is probably due to the small number of observations, and the difficulty in keeping the instrument in adjustment and allowing for its irregularities. I have, therefore, given the mean ratio of the Philadelphia disturbances in the last column of Table VII, and compared the result, graphically, with those deduced by General Sabine for Toronto.[1]

ANNUAL INEQUALITY OF DISTURBANCES.



If we separate the disturbances into two parts, those increasing and those decreasing the force, we obtain the numbers of Table VIII. A positive sign indicates disturbances increasing, a negative sign those decreasing the vertical force. The law of the annual variation seems to be the same as shown by the ratios in the last two columns; this accords with the result at Toronto.

TABLE VIII.—ANNUAL INEQUALITY OF DISTURBANCES INCREASING AND DECREASING THE FORCE.

	1841–42.		1842–43.		1843–44.		1844–45.		Ratios.	
	+	—	+	—	+	—	+	—	+	—
July	31	33	8	16	0	4	12	10	0.7	1.1
August	14	7	9	25	8	2	36	11	1.0	0.8
September	22	18	16	41	9	11	5	2	0.7	1.2
October	22	6	8	4	6	6	3	7	0.6	0.4
November	17	20	5	8	14	26	4	1	0.6	1.0
December	51	33	8	7	23	10	13	10	1.4	1.1
January	38	38	32	26	26	14	6	3	1.5	1.5
February	53	33	32	19	11	5	2	1	1.4	1.0
March	16	20	23	21	30	23	23	11	1.3	1.3
April	32	19	30	20	23	19	5	7	1.3	1.1
May	28	19	18	18	3	1	11	3	0.9	0.7
June	23	14	5	11	7	19	3	1	0.6	0.8

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[1] Page lxx., Vol. III.

TABLE IX.—AGGREGATE AND MEAN AMOUNT OF DISTURBANCES IN EACH MONTH OF THE YEAR.

The numbers are expressed in scale divisions and referred to a uniform series of bi-hourly observations. The mean amount or average magnitude is found by dividing the number in the preceding column by 4 and by the number of disturbances found in Table VII.

	Aggregate amount.				Sum of 4 years.	Mean amount.
	1841–42.	1842–43.	1843–44.	1844–45.		
July . . .	2593	1255	149	784	4781	42
August . .	791	1323	622	2017	4753	43
September .	1612	2798	770	301	5481	44
October . .	1216	432	488	438	2574	42
November .	1564	503	1504	206	3777	40
December .	4187	560	831	872	6450	42
January . .	3899	2745	1592	314	8550	47
February . .	3900	2279	659	109	6947	45
March . . .	1672	1898	2125	1245	6940	42
April . . .	2324	2111	1642	468	6545	42
May . . .	2445	1625	186	704	4960	49
June . . .	1472	723	934	168	3297	40

The last column shows that the magnitude of the disturbances is rather irregularly distributed over the several months without following any apparent law.

TABLE X.—AGGREGATE AND MEAN AMOUNT OF DISTURBANCES IN EACH MONTH OF THE YEAR, SEPARATED INTO TWO GROUPS OF INCREASING (+) AND DECREASING FORCE (—).

The mean amount is obtained by means of the numbers of Table VIII.

	1841–42.		1842–43.		1843–44.		1844–45.		Sum of 4 years.		Mean amount.	
	+	—	+	—	+	—	+	—	+	—	+	—
July	1130	1463	340	915	0	149	402	382	1872	2909	37	46
August	555	236	359	964	279	343	1568	449	2761	1992	41	45
September	835	777	775	2023	397	373	251	50	2258	3223	43	45
October	999	217	300	132	250	238	128	310	1677	897	43	39
November	653	911	223	280	504	1000	154	52	1534	2243	38	41
December	2745	1442	276	284	508	323	489	383	4018	2432	42	41
January	2128	1771	1589	1156	1050	542	208	106	4975	3575	48	44
February	2615	1285	1538	741	462	197	76	33	4691	2256	48	39
March	671	1001	910	988	1149	976	875	370	3605	3335	39	44
April	1471	853	1361	750	853	790	172	296	3856	2689	43	41
May	1535	910	928	697	170	16	598	106	3231	1729	54	42
June	999	473	246	477	246	688	133	35	1624	1673	43	37
Sums	16336	11339	8845	9407	5867	5635	5054	2572	36102	28953		
									Mean . . .		43	42

The magnitudes of the disturbances, as before, do not appear to follow any law. The disturbances which increase the force preponderate over those which decrease it; the ratio of the annual means is 1.3 to 1.0. At Toronto the reverse was found; the disturbances which decrease the force preponderate over those which increase in the ratio of 1.4 to 1.0.

Diurnal Inequality of the Disturbances.—In the bi-hourly combination of the disturbances we make use of the series of observations extending from February, 1841, to June, 1845, omitting only the single daily observation in January, February, and March, 1843. Strictly speaking the time is 21 minutes later than indicated in the table.

TABLE XI.—DIURNAL INEQUALITY IN THE NUMBER OF DISTURBANCES.
The ratios of the three elements have been collected to facilitate comparison.

	Number vertical force.	Ratios.		
		Vertical force.	Horizontal force.	Declination.
0h	168	1.3	1.1	1.0
2	159	1.2	0.9	1.2
4	156	1.2	0.7	1.0
6	133	1.0	0.7	1.1
8	117	0.9	0.8	1.0
10	115	0.8	1.1	1.1
Noon	131	1.0	1.3	0.9
14	163	1.2	1.0	0.8
16	127	0.9	1.1	0.9
18	116	0.8	1.1	0.9
20	110	0.8	1.1	1.0
22	123	0.9	1.1	1.1
Mean	135			

The greatest number of disturbances occur about A. M. (at Toronto at 3 A. M.), with the least number at 10 A. M. (at Toronto at 11 A. M.); the secondary maximum and minimum occur about 2 P. M. and 7 P. M. (at Toronto the hours are 5 P. M. and 9 P. M.). On the average, therefore, the maxima and minima occur 1h 40m earlier at Philadelphia than at Toronto. At neither station do the three elements show the same law; they agree only in so far as to exhibit a systematic increase and decrease with the solar hours, and in having two maxima and two minima.

The diagram shows the law of the disturbances of the vertical force for Philadelphia and Toronto.

DIURNAL VARIATION OF DISTURBANCES.

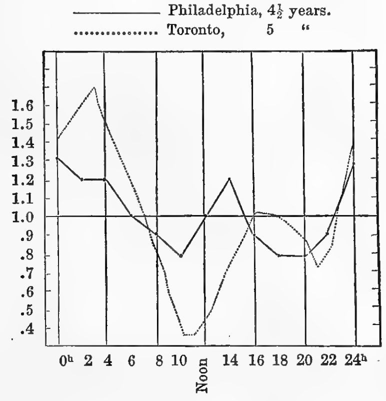

Table XII.—Contains the number of Disturbances distributed over the Hours of the Day, separated into those which Increase (+) and those which Decrease (—) the Vertical Force.

	Number of disturbances.		Ratios.	
	+	—	+	—
0h	93	75	1.3	1.2
2	73	86	1.0	1.3
4	69	87	1.0	1.4
6	62	71	0.9	1.1
8	59	58	0.8	0.9
10	53	62	0.8	1.0
Noon	61	70	0.9	1.1
14	96	67	1.3	1.0
16	69	58	1.0	0.9
18	72	44	1.0	0.7
20	67	43	0.9	0.7
22	76	47	1.1	0.7
Mean	71	64		

The laws which regulate the diurnal occurrence of the number of disturbances, increasing and decreasing the vertical force, are evidently not the same, yet they are by no means the converse of one another as has been found to be the case in the disturbances of the declination and the horizontal force. At Toronto also, where the horizontal force and declination curves were exactly opposed, that of the vertical force is not so, and at Philadelphia rather favors an agreement between the increasing and decreasing disturbances than an opposition.

Principal maximum of increasing disturbances 2 P.M., principal minimum 9 A.M. (at Toronto 5 P. M. and 5 A. M. respectively). Secondary maximum at midnight; this may possibly be the principal maximum; secondary minimum at 8 P. M.

Principal maximum of decreasing disturbances 4 A. M., principal minimum 8 P. M. (at Toronto 3 A. M. and 6 P. M. respectively). The secondary maximum at noon is less distinctly marked; secondary minimum at 8 A. M.

Thus the epochs of the curves for increasing and decreasing force seem to be 12 hours apart.

Diurnal Inequality in the Magnitude of the Disturbances.

Table XIII.—Contains the aggregate amount of Disturbances and their average Magnitude, the latter found by means of Table XI. All expressed in Scale Divisions.

	Aggregate amount.	n	Mean amount.
0h	7049	168	42
2	6876	159	43
4	6480	156	42
6	5418	133	41
8	5022	117	43
10	5096	115	44
Noon	5526	131	42
14	7101	163	44
16	5591	127	44
18	5571	116	48
20	4773	110	43
22	5246	123	43

Average magnitude 43 scale divisions, the disturbances appear to be nearly of the same size at all hours, there is a slight preponderance in magnitude between 10 A. M. and 10 P. M. over the other half of the day.

Table XIV.—Aggregate amount and mean amount of Disturbances, separated into those which increase and those which decrease the Vertical Force.

	Aggregate amount.		Mean amount.		Difference of aggregate amount.
	+	—	+	—	
0h	3737	3312	40	44	+ 425
2	3221	3655	44	43	— 434
4	2866	3614	42	42	— 748
6	2577	2841	42	40	— 264
8	2524	2498	43	43	+ 26
10	2507	2589	47	42	— 82
Noon	2731	2795	45	40	— 64
14	4456	2645	46	40	+1811
16	2969	2622	43	45	+ 347
18	3456	2115	48	48	+1341
20	3003	1770	45	41	+1233
22	3258	1988	43	42	+1270
Mean			44.0	42.5	+4861

The magnitude of the disturbances, either increasing or decreasing the force, apparently does not vary with the hours of the day. The disturbances which increase the force preponderate between the hours 2 P. M. and 2 A. M.; those which decrease the same occur in the other half of the day, the average ratio of the preponderance of increase over decrease is as 4 to 1.

Dividing the numbers in the last column of the preceding table, or the excess of the sum of disturbances increasing the force over the sum of those decreasing the same, by the total number of days (1297) of observation, we find the diurnal disturbance variation as follows:—

	Scale divisions.	In parts of vertical force.	In absolute measure.
0h	+0.3	+0.00001	+0.00013
2	—0.3	—0.00001	—0.00013
4	—0.6	—0.00002	—0.00025
6	—0.2	—0.00001	—0.00008
8	0.0	0.00000	0.00000
10	—0.1	0.00000	—0.00004
Noon	0.0	0.00000	0.00000
14	+1.4	+0.00004	+0.00059
16	+0.3	+0.00001	+0.00013
18	+1.0	+0.00003	+0.00042
20	+1.0	+0.00003	+0.00042
22	+1.0	+0.00003	+0.00042
Mean	+0.3	+0.00001	+0.00013

The value for the hour 14 is evidently anomalous, the mean of the hours 12 and 16 or $+ 0^d.2$ (0.00001 in parts of force, 0.00008 in absolute measure) should be substituted. The average daily effect of the larger disturbances is therefore to increase the vertical force between 1 P. M. and midnight, and to decrease it between 1 A. M. and noon, with an amplitude of about 1.6 scale division (0.00005 parts of the force, 0.00067 in absolute measure). The maximum value takes place at 8 P. M., the same hour at which the horizontal force disturbance is greatest (decreasing that force).

The disturbance law at Toronto is nearly the same as at Philadelphia, the disturbances increase the force between noon and 9 P. M., and decrease it in the remaining hours of the day; the range at Toronto appears to be larger.

If we classify the disturbances according to their magnitude in eight groups, each differing 25 scale divisions from the preceding, we find the following scale numbers:—

Disturbances. In scale divisions.	Between limits in parts of the force.	Number.
30 and 55	0.00099 and 0.00181	1840
55 " 80	0.00181 " 0.00263	211
80 " 105	0.00263 " 0.00346	28
105 " 130	0.00346 " 0.00428	15
130 " 155	0.00428 " 0.00511	0
155 " 180	0.00511 " 0.00593	2
180 " 205	0.00593 " 0.00676	0
205 " 230	0.00676 " 0.00759	1
Beyond		None.

APPENDIX TO PART VII.

EFFECT OF THE AURORA BOREALIS ON THE MAGNETIC DECLINATION, AND THE HORIZONTAL AND VERTICAL FORCE AS OBSERVED AT THE GIRARD COLLEGE OBSERVATORY.

THERE were in all 22 auroras recorded; these, however, comprise only the brighter displays. Of those observed, 7 occurred between May 30, 1840, and July 1, 1841; 1 occurred between July, 1841, and July, 1842; 6 occurred between July, 1842, and July, 1843; and 7 between July, 1843, and July, 1844. One is recorded in the last year, ending June 30, 1845. They are distributed over the several months as follows:—

January	2	July	6
February	0	August	3
March	1	September	2
April	2	October	0
May	3	November	1
June	2	December	0

In the summer months there were 18, in the winter months 4. In reference to the hours of the night, the phenomenon was visible on the average between $9\frac{1}{2}$ P. M. and $11\frac{1}{4}$ P. M.

Individual examination of the magnetic record during auroral displays. The time is local time, counted for convenience' sake from midnight to midnight to 24 hours.

I. 1840, May 29th—30th. As the twilight faded an aurora became visible. In the course of the display there were moving pillars, flashes from a low segment of light in the north, and a beautiful arch nearly or quite at right angles to the magnetic meridian. Pillars of aurora from $21^h\ 18^m$ to $22^h\ 2^m$, varying in brightness and position; low segment of light to the north, continued throughout the appearances; at $22^h\ 5^m$ an arch forms from east to west; streams of light, varying in brightness, fading and reappearing from $22^h\ 20^m$ to about $23^h\ 10^m$; the brightest flash at $23^h\ 6^m$. From $18^h\ 54^m$ the declination magnet commenced to move eastward (declination decreasing), reaching an extreme position at $20^h\ 34^m$, difference from average position about 56 divisions or 19′; the movement then became westerly with smaller fluctuations till $22^h\ 39^m$, when it reached its westerly extreme of about 71 divisions or 24′ from the normal place; the magnet reached a second easterly extreme at $23^h\ 44^m$ of about 48 divisions or 17′, at $1^h\ 24^m$ (30th) again a westerly extreme of about 7′, and at $2^h\ 49^m$ an easterly deflection of about 14′; after this the needle returned gradually to its ordinary position. About the time of the brightest flash the change (easterly motion) was very rapid, no extreme value, however, was reached. When the arch formed, the position was nearly normal. The horizontal force decreased steadily until $22^h\ 42^m$, when the readings fell beyond the scale; a minimum was reached between that time and $22^h\ 52^m$ of at least 0.016 (parts of the force) below the normal force. At the time of the brightest flash the retrograde movement was in progress. The disturbance of the vertical force commenced before $17^h\ 52^m$, at which time the force was a maximum; it then decreased very rapidly, and finally moved off the scale after $22^h\ 2^m$. (The value of a division of the scale was not ascertained.)

II. 1840, July 4th. At 20^h auroral light in the N. N. W. about 10° above the horizon, at 22^h very faint aurora still visible in N W. The declination was not at all affected. The horizontal force at these hours was 85 divisions (0.003 parts of the force) less than the normal amount. The vertical force is apparently undisturbed; it is slightly above the normal value.

III. 1840, July 6th. An aurora was noticed at $0^h\ 25^m$ and $2^h\ 25^m$. The declination was disturbed at $0^h\ 19\frac{1}{2}^m$ and $2^h\ 19\frac{1}{2}^m$; it indicated 50 divisions and 34 divisions, or 17′ and 12′ of easterly deflection. It is likely that there were disturbances two hours preceding and two hours following the above times, as the scale could not be read. The horizontal force was disturbed from midnight till 2 P. M.; the force was less during this time, and reached its minimum value at $2^h\ 22^m$ of 130 divisions or 0.005 parts of the force; between 2 and 8 A. M. the diminution was about 0.004 parts. The vertical force was also less from midnight till after $2^h\ 17^m$, the greatest diminution probably took place later as the observations failed at $4^h\ 17^m$. Minimum value at $2^h\ 17^m$, 0.004 parts of the force.

IV. 1840, July 29th. At $22^h\ 25^m$ a faint aurora. The declination was not disturbed. The horizontal force was very slightly affected. At $20^h\ 22^m$ it was 0.001 parts less than the normal, at $22^h\ 22^m$ it was nearly normal, and at $0^h\ 22^m$ (30th) it was greater by 0.002. There may have been ordinary disturbances not immediately connected with the aurora. At $22^h\ 17^m$ the vertical force was slightly affected, the force decreased 0.002 parts below the normal.

V. 1840, August 19th. At $20^h\ 25^m$ auroral light in N.; $22^h\ 25^m$ aurora continues in N. and N. W. The declination disturbance commenced at $22^h\ 20^m$ and continued to $2^h\ 20^m$ (20th), west deflection 48 divisions (22′), 10 divisions, and 10 divisions. The horizontal force was disturbed from $16^h\ 22^m$ to $22^h\ 22^m$, force less 43 divisions, 49, 102, and 85 divisions (in minimo 0.004 parts of the force). The vertical force seems lower than usual, but hardly reached the limit of a recognized disturbance.

VI. 1840, August 28th and 29th. An aurora appeared at $20^h\ 39\frac{1}{2}^m$ in N. N. E., disappeared at $21^h\ 19\frac{1}{2}^m$, reviving at $21^h\ 59\frac{1}{2}^m$; at $22^h\ 9\frac{1}{2}^m$ streamers moving from E. to W.; light continued in N.; streamers again in N. E. at $22^h\ 59\frac{1}{2}^m$ and $1^h\ 14\frac{1}{2}^m$, after which time the aurora was not observed. An easterly movement of the needle commenced about $20^h\ 19^m$ with a maximum eastern deflection of 125 divisions (or 57′) at $21^h\ 0^m$, the westerly motion continued till $21^h\ 55^m$ when the needle was yet 5′ east of its normal position; smaller fluctuations were observed till midnight, the deflection was then 19′ east; half an hour later it was 20′ east; the morning extreme was reached at $1^h\ 35^m$, when the deflection was 25′ east; after this the disturbance gradually subsided. There was a disturbance of the horizontal force about $18^h\ 20^m$; from about $21^h\ 52^m$ till 10 the next morning the horizontal force remained below its normal value. At $23^h\ 32^m$ it was 0.009 (parts) below, at $0^h\ 22^m$ it was 0.007, and at $1^h\ 22^m$ its minimum value of 0.010 (parts of the force) was reached. The disturbance in the vertical force appears to have commenced about $21^h\ 7^m$, when the force gradually decreased till $21^h\ 57^m$ when it reached a minimum of about 0.003 (parts); after this it gradually increased.

VII. 1840, September 21st. At $20^h\ 25^m$ faint aurora, $22^h\ 25^m$ aurora disappeared. Disturbance of the declination commenced at $20^h\ 20^m$ and continued to $4^h\ 20^m$ (22d), deflections 40 divisions (18′) W., 10 divisions E., 14 divisions W., and 23 divisions E. The horizontal force disturbance commenced at $16^h\ 22^m$ and ceased at $4^h\ 22^m$ next day; force less 69 divisions, 47 divisions, 71 divisions, 42 divisions, 94 divisions, 124 divisions (0.005 parts of the force), and 93 divisions. The vertical force between 16^h and 23^h was slightly above the average, but suddenly became much smaller than the normal between midnight and 3 A. M. Minimum about 0.002 parts of the force.

VIII. 1842, April 14th. At $22^h\ 40^m$ appearance of aurora, a bright light in the N.; at $0^h\ 20^m$ (15th) an arc of light was visible extending to about 15° above the north horizon. Declination disturbed from $22^h\ 20^m$ to $8^h\ 20^m$ (15th), deflections at the regular observing hours 23 divisions W., 39 E., 11, 37, 10, and 14 divisions W. Maximum west deflection at $22^h\ 56^m$, 58 divisions (26′), maximum east deflection 39 divisions (18′), derived from the series of extra observations. The horizontal force disturbances commenced at $22^h\ 22^m$ and ceased at $4^h\ 22^m$, force less 39 divisions, 149 divisions, 37 divisions, and 50 divisions, minimum 279 divisions (0.010 parts of the force) at $1^h\ 16^m$ (15th). But one of the 69 extra readings during this aurora shows an increase of force. The vertical force disturbances commenced at $0^h\ 17\frac{1}{2}^m$ (15th) and continued to $6^h\ 17\frac{1}{2}^m$; force less 68 divisions, 69 divisions, 59 divisions, and 38 divisions. Minimum value 111 divisions or 0.0037 parts of the force at $1^h\ 24^m$ (15th).

IX. 1842, September 2d. At $2^h\ 22^m$ a bright light extending on each side of N. point about 15°, and to about 6° above the horizon; at $2^h\ 49^m$ light spreading and becoming more faint; at $3^h\ 12^m$ light faint and gradually subsiding. The declination was very slightly affected, maximum west deflection at $3^h\ 26^m$, 19 divisions (9′). The horizontal force was not disturbed. The vertical force was likewise undisturbed

X. 1842, November 21st and 22d. A well developed aurora and the best observed of the series. At $22^h\ 23^m$ a very luminous arc extending to about 15° above the horizon, and about 90° along it in the north; $22^h\ 38^m$ light slightly increasing; $22^h\ 53^m$ a slight decrease of light; $23^h\ 18^m$ light alternately appearing and disappearing; $23^h\ 33^m$ four streamers of unusual brightness reaching 30° above horizon; $23^h\ 36^m$ light particularly bright in N. W., whence a large streamer of 20° is shooting, also one due north of 15°; $23^h\ 40^m$ light subsided, no streamers; $23^h\ 43^m$ small streamers appearing; $23^h\ 46^m$ large streamers attended with great light in N. W.; $23^h\ 48^m$ the arc still remains about 15° above horizon, but has shortened its chord to 30°, no streamers; $23^h\ 51^m$ arc scarcely visible; $0^h\ 23^m$ (22d) two arcs visible; $0^h\ 28^m$ a large streamer of 20° in length; $0^h\ 36^m$ considerable light without the arc; $1^h\ 08^m$ light very faint; $1^h\ 23^m$ slight appearances of arc; $1^h\ 33^m$ faint streamer of 10°; $1^h\ 58^m$ faint streamer of 20°; $2^h\ 48^m$ a large but faint streamer due N. about 20° in length; light has nearly disappeared; $3^h\ 3^m$ light scarcely visible; $3^h\ 33^m$ no light visible, and readings of instrument ordinary. The declination disturbances commenced at $22^h\ 20^m$, and ceased at $10^h\ 20^m$ (22d); deflections 49 divisions W., 20 divisions W., 25, 20, 8, 25, and 16 divisions E. The maximum W. deflection (22′) occurred at the commencement, with the appearance of the luminous arc, the needle remained deflected to the westward until towards the end, when there was a smaller easterly deflection. No special effect of the streamers is noticed. The horizontal force disturbances commenced at $16^h\ 22^m$, and continued to $2^h\ 22^m$ (22d); horizontal force less 33 divisions, 68, 82, 183 divisions (0.007 parts of the force); this diminution was about the time of the appearance of the arc, 125 divisions and 73 divisions at the last two regular observing times. The streamers did not appear to have any special effect. The horizontal force always remained smaller than the normal value at the respective hours. The vertical component was not affected.

XI. 1843, May 6th and 7th. At $19^h\ 48^m$ a bright light; at $2^h\ 18^m$ (7th) light to N. about 23° high, but faint. The declination disturbances commenced at $16^h\ 20^m$, and continued to about 3^h (7th). The deflections at the regular hours were 28, 30, 16 divisions E., 15 divisions W. (20^m after midnight), maximum east deflection 18′, succeeding maximum west deflection 9′, next following maximum east deflection 33′, following maximum west deflection 15′. The horizontal force disturbances commenced at the same hour with the declination disturbances, and continued to the end of the series of observations. The change commenced with a violent increase of 113 divisions above the normal value, and increased to 330 divisions (0.012 parts of the force) at $18^h\ 04^m$, corresponding in time to the first maximum east deflection. The force then decreased, reaching 132 divisions below the normal value, and attaining shortly (16^m) after midnight the extraordinary low value 348 divisions (0.013 parts of the force); up to the end of the disturbance the force remained below the standard amount. The vertical force was suddenly disturbed, at $18^h\ 23\frac{1}{2}^m$ it was 161 divisions greater than the mean, and at $22^h\ 23\frac{1}{2}^m$ but 41 divisions above the normal. Maximum value 164 divisions (equal to 0.0054 parts of the force) at $18^h\ 12^m$.

XII. 1843, May 8th. At 0^h an aurora visible to north. The declination was but slightly affected; at $19^h\ 32^m$ there was an easterly deflection of 15 divisions or 7′; at $20^h\ 26^m$ it was west 4′; after this there was an easterly motion, changing again to west, which reached an extreme value at $23^h\ 44^m$ of 17 divisions or 8′ W. From the commencement of the horizontal force observations ($17^h\ 38^m$) the force was less than the normal; at $20^h\ 4^m$ the greatest depression was 0.003 (parts of the force). The disturbance continued till 6 A. M., the force being less than the standard value. From $17^h\ 38^m$, when the vertical force was observed, it was found less than the normal, at $20^h\,36^m$ depression 20 divisions, at $0^h\,23^m$ it was 31 divisions or 0.001 parts of the force below the standard value.

XIII. 1843, June 27th. At 22^h a bright diffused light to north, particularly bright to N. W., whence streamers are shooting up; general light weakens as it rises at $20^h\,45^m$; at $21^h\,15^m$ a brilliant light, dark cumulus spots in the bright light, and long streaks of dark clouds to N. Fades at $22^h\,13^m$, light to N. faint; dark, fuzzy, low cumuli form and disappear to N. Neither the declination nor the horizontal force was disturbed by this aurora. The vertical force was slightly affected, force less 38 divisions or 0.0012 parts of the force.

XIV. 1843, June 30th. At 23^h aurora visible to the N. N. E., flaming to about 10°. The declination disturbances commenced at $22^h\,20^m$ (9 divisions W.), they reach a maximum at $0^h\,02^m$ (July 1st) of 20 divisions (9′), and gradually disappear, the deflections having been west throughout. The horizontal force is smaller than the normal value, a first minimum is reached about $20^h\,44^m$ (about 45 divisions), and the principal minimum about $0^h\,10^m$ (July 1st) of nearly 50 divisions (0.0018 parts of the force). The vertical force remained undisturbed.

XV. 1843, July 7th. At $20^h\,52^m$ very light in the N. N. E. and N. W. The declination at $18^h\,20^m$ is deflected 15 divisions E., the motion then became westerly and reached 29 divisions (13′) W. at $23^h\,33^m$; at $2^h\,20^m$ (8th) the deflection is again 16 divisions W. The horizontal force is less than usual, with a minimum value about $20^h\,52^m$ of 55 divisions (0.002 parts). The force then increases, and about midnight reaches slightly above the normal. The vertical force was not disturbed.

XVI. 1843, July 24th and 25th. According to a letter (dated July 25th) from one of the observers, auroral disturbances commenced about 16^h (July 24th) and quieted down about 21^h. At $16^h\,20^m$ the declinometer was deflected 15 divisions E., about 4^h (25th) the disturbances reappeared deflecting 10 divisions W., and changed to east deflection at $6^h\,20^m$, reaching a maximum east of 34 divisions (15′) at $13^h\,20^m$. At $16^h\,22^m$ the horizontal force was about 46 divisions less, with disturbances reappearing about $8^h\,22^m$, reaching at $8^h\,46^m$ 96 divisions (0.0015 parts of the force) below the normal, and quieting down about one hour after noon. The vertical force was not sensibly disturbed.

XVII. 1843, July 25th. At $21^h\,30^m$ (25th) streamers to N., flaming to about 30°; at 22^h streamers very bright, reaching about 40°; At $22^h\,15^m$ light very faint and gradually disappearing. The declination was disturbed (deflections west) between $20^h\,20^m$ and $22^h\,20^m$ reaching a maximum at $21^h\,58^m$ of 36 divisions (16′). The horizontal force decreased between $18^h\,22^m$ and $22^h\,22^m$, reaching at $21^h\,34^m$ 91 divisions (0.0033 parts) below the normal value. The vertical force apparently undisturbed.

XVIII. 1843, August 22d. At $20^h\,22^m$ there were streamers of 35° in length, bright light in N. Between $14^h\,20^m$ and $18^h\,20^m$ there was a small east deflection of the magnet reaching 28 divisions at the latter hour; at $19^h\,56^m$ it changed to a west deflection of the same amount (13′). At the time of the appearance of the streamers the declination was normal. During the aurora the horizontal force diminished, reaching at $20^h\,28^m$ 91 divisions (0.0033 parts) below the normal. The low value continued for about two hours after this time. The vertical force was not sensibly affected.

XIX. 1844, January 24th and 25th. Aurora visible to N. and N. N. E. at $0^h\,22^m$ (25th), streamers running up 30°; $0^h\,33^m$ streamers running up 15° and 20°. During this aurora the horizontal needle was deflected to the westward about 10 divisions, reaching a maximum at $6^h\,58^m$ of 15 divisions (7′); at the time of the appearance of the shorter streamers the deflection was near 7′, the horizontal force was below the normal value, viz: decrease 36 divisions, 41 and 35 divisions at $22^h\,22^m$, $23^h\,22^m$, and $0^h\,22^m$ (25th), minimum 47 divisions (0.0017 parts). At the time of the longer streamers there was an average decrease, and during the continuance of the shorter streamers the horizontal force was normal. At $0^h\,23\frac{1}{2}^m$ and $2^h\,23\frac{1}{2}^m$ the vertical force was 36 and 32 divisions smaller than the normal. Difference 0.0011 parts of the force.

XX. 1844, March 29th. At $16^h\,51^m$ cloudy, aurora visible. The declination magnet is deflected to the east and west several times in succession; between $16^h\,20^m$ and $18^h\,20^m$ about 14 divisions E., and 16 divisions E.; the following greatest west deflection of 61 divisions (27′) occurred at $20^h\,10^m$; the next east deflection reached a maximum at $0^h\,22^m$ (30th) of 41 divisions; a maximum west deflection was again reached at $1^h\,14^m$ of 50 divisions (23′). The horizontal force is throughout smaller than the normal value, with differences varying on the average from 50 to 70 divisions. The greatest difference was reached at $20^h\,2^m$ of nearly 100 divisions (0.0036 parts of the force); at $23^h\,47^m$ another small value of 90 divisions was observed. The vertical force was disturbed from $21^h\,23\frac{1}{2}^m$ to $4^h\,23\frac{1}{2}^m$ (30th). Force less 49 divisions, 55, 44, 73, 49, 52, 55, and 31 divisions. Minimum value 0.0024 parts of the force.

XXI. 1844, April 17th. At $2^h\,20^m$, although cloudy, it was very bright at the north; same remark at $22^h\,20^m$. The declination disturbances extend nearly over the whole day. The deflection was at first west (between $0^h\,20^m$ and $4^h\,20^m$) with a maximum value of 48 divisions (22′) at $3^h\,10^m$; it then changed to the east, at $6^h\,04^m$ it reached 52 divisions (23′); up to $20^h\,20^m$ the deflection was slightly to the east. The horizontal force was diminished early in the morning, attaining a first minimum at $2^h\,40^m$ of 47 divisions; it increased for a short time, reaching at $4^h\,14^m$ 52 divisions above the normal, the force again decreased and reached at $5^h\,47^m$ the lowest value of 151 divisions (0.0055 parts); it remained below the normal value for several hours. At $19^h\,53^m$ the diminution was 41 divisions. Vertical force disturbed from 3^h to 8^h ($+23\frac{1}{2}^m$), force less 52 divisions, 58, 61, 66, 53, and 35 divisions. Minimum value 0.0022 parts of the force.

XXII. 1845, January 9th. At $17^h\,20^m$ an aurora visible. The declination magnet is deflected east and west alternately; first maximum east deflection at $16^h\,32^m$ of 20 divisions; following maximum west at $17^h\,02^m$ of 11 divisions; following east deflection about 20 divisions 12^m later; next west deflection at $17^h\,22^m$ 21 divisions; at $19^h\,56^m$ the deflection again east 32 divisions; at $21^h\,38^m$ it is west 40 divisions (18′), at $22^h\,20^m$ it is east 33 divisions. The horizontal force between $15^h\,52^m$ and midnight is considerably smaller than the normal value, a minimum is reached at $17^h\,16^m$ of 155 divisions (0.0056 parts of the force). The disturbances ceased between 2^h and 3^h on the morning of the 10th. The vertical force was disturbed at 17^h; 20, 22, and 23^h ($+23\frac{1}{2}^m$), force greater 44 divisions, 31, 35, and 33 divisions. Average increase 0.0012 parts of the force.

From the preceding detailed account of the condition of the declination and of the horizontal and vertical components of the magnetic force during auroral displays, we obtain the following general results: Each of the 22 auroras recorded was accompanied by a corresponding disturbance of the earth's magnetism, at least in one of the three elements; in one case the declination alone was affected, in another case only the horizontal force, and in a third only the vertical force. The latter force was less subject to disturbances than the other two elements.

In the following table, showing the condition of the magnetic components during auroras, the first column contains the number of the aurora, the second the amount of declination deflection, the third its direction or the successive large excursions of the north end eastward or westward; the fourth the amount of the horizontal force disturbance expressed in parts of that force (a minus sign indicates less force than the normal belonging to that time, a plus sign indicates the reverse), the last column contains the amount of disturbance in the vertical force expressed in parts of that force; the signs have the same signification as for the horizontal force.

Number.	Amount of deflection.	Direction of deflection and excursions.	Excess (+) or defect (—) of horizontal force.	Excess (+) or defect (—) of vertical force.
1	24′	E. W. E. W. E.	—0.016	— (?)
2			—0.003	
3	17	E.	—0.005	—0.004
4			∓0.002	—0.002
5	22	W.	—0.004	
6	57	E.	—0.010	—0.003
7	18	W. E. W. E.	—0.005	—0.002
8	26	W. E. W.	—0.010	—0.004
9	9	W.		
10	22	W. E.	—0.007	
11	33	E. W. E. W.	±0.013	+0.005
12	8	E. W. E. W.	—0.003	—0.001
13				—0.001
14	9	W.	—0.002	
15	13	E. W.	—0.002	
16	15	E. W. E.	—0.002	
17	16	W.	—0.003	
18	13	E. W.	—0.003	
19	7	W.	—0.002	—0.001
20	27	E. W. E. W.	—0.004	—0.002
21	23	W. E.	∓0.006	—0.002
22	18	E. W. E. W. E. W. E.	—0.006	+0.001

The action on the declination magnet appears to be that of alternate deflections either way from the normal position; in 5 cases the deflection was west, in 2 cases east, more frequently there were one or two successions of west and east deflections (or the reverse) in one instance even three; these alternate excursions appear to be a characteristic sign. In 5 cases the tendency of the deflection was easterly, in 6 cases westerly, and in the remaining 8 cases in both directions. The average amount of deflection is 17′. With but one exception the uniform effect upon the horizontal force was to decrease it. In the exceptional case a decrease followed the increase; in another case the reverse took place; during one aurora there was at first a fall in the force, then a rise, and again a fall. The average depression of the horizontal force below the normal value was 0.005 parts of the force (0.021 in absolute measure). The effect upon the vertical force is small; in 9 cases no disturbance occurred; in general the force is less than the normal; there are two exceptions to this in the 13 cases. The average depression of the vertical force below its normal was 0.0007 parts of the force (0.009 in absolute measure), or irrespective of sign 0.0013 parts of the force. If we wish to compare the tabular differences in declination and horizontal and vertical force with the magnitude of the recognized disturbances, the latter are 4′ and 0.001 (parts of the force) for either the horizontal or vertical component.

Of the auroras noted, that of May 29, 1840, was in many respects the most remarkable, and the best observed both as to its appearance and as to its magnetic effect; its study can be recommended to those who have occasion to test their theoretical views in reference to this phenomenon, and to terrestrial magnetism. Its appearance at New Haven, Conn., has been described by E. C. Herrick (Sill. Jour., 1840, Vol. XXXIX, p. 194). It was seen over a great portion of the United States, in Canada, and England. See, also, description in the volume of the Toronto Observations; also an extract from the proceedings of the British Association (Sill. Jour. Vol. XL, p. 337); also (p. 338 ibid.) note on the same by the Astronomer Royal.

The total number of auroras which occurred at Philadelphia was much greater than the number given above, as has already been stated. At Toronto the annual distribution of the phenomenon over the same period of time, and for three years beyond the close of the record at Philadelphia, is as follows:—

In 1840 (from March)	on 23 nights.
" 1841	36 "
" 1842	14 "
" 1843	16 "
" 1844	20 "
" 1845	19 "
" 1846	27 "
" 1847	29 "
" 1848	66 "

These figures seem to indicate the existence of a period of frequency, probably of eleven years as conjectured by Prof. Wolf, the least number probably occurred in 1843, if we make an allowance for invisibility of the phenomenon either by daylight or by cloudy weather.

Between June, 1840, and July, 1845 (incl.), there were seen, according to the Toronto record, 109 auroras. The disturbances at Philadelphia on the dates of their appearance have been classified as follows: The numbers give the relative proportion to the total number, which latter is expressed by 100; the average numbers are given resulting from the examination of the disturbances of the declination, the horizontal and the vertical force.

	Number of cases.
No record at Philadelphia	19
None of the elements disturbed	30
But very few disturbances	20
An ordinary number of disturbances	14
An unusual number of disturbances	17

The number of unusual disturbances is therefore less than one-fifth of the total amount, and in fully one-half of the cases the magnetic elements were either not at all or but very slightly affected.

PART VIII.

INVESTIGATION

OF THE

SOLAR-DIURNAL VARIATION AND OF THE ANNUAL INEQUALITY OF THE VERTICAL COMPONENT OF THE MAGNETIC FORCE.

DISCUSSION

OF THE

SOLAR DIURNAL VARIATION, AND OF THE ANNUAL INEQUALITY OF THE VERTICAL COMPONENT OF THE MAGNETIC FORCE AT PHILADELPHIA.

THE necessary data for this investigation are given in the preceding Part (VII), which contains the normals resulting from the reduction of the observations to the same temperature (66° Fah.), from the allowance for irregularity in the progressive change and the exclusion of all recognized disturbances.

Owing to the greater irregularity in the indications of the vertical force instrument, and the comparatively small number of observations at odd hours, the normals are given for the even hours only; the observations at odd hours, however, are used to improve those taken at the intermediate even hours by means of a suitable process of interpolation.

The tabular numbers are expressed in scale divisions, one division being equal to 0.000033 parts of the vertical force, or equal to 0.000423 in absolute measure. Increasing numbers denote decrease of force. The hours count from midnight to midnight to 24 hours; the number of minutes the observations are made later than the full hour are given in the last column for each month.

NORMALS OF THE VERTICAL FORCE FOR JULY.

Year.	0^h	1	2	3	4	5	6	7	8	9	10	11^h
1841	703		697		687		671		667		664	
1842	683		672		664		659		657		650	
1843	691		692		692		686		679		672	
1844	816	811	804	806	805	802	798	793	784	783	782	780
Means[1]	722		717		712		703		698		692	

Noon	13	14	15	16	17	18	19	20	21	22	23^h	Min.
665		676		680		698		708		706		+17
643		643		647		663		677		682		+17½
662		658		659		666		677		685		+23½
780	776	773	781	783	791	799	805	808	809	811	816	+23½
687		688		693		706		717		721		+20.4

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[1] Let reading for any even hour $=n$ for the year 1844, for the odd hours preceding and following $n\,p$ & $n\,f$, mean $\frac{n\,p+n\,f}{2}$; hence mean for the even hour $\frac{1}{2}\left(n+\frac{n\,p+n\,f}{2}\right)$ which was substituted before the general mean for the four years was taken.

Normals of the Vertical Force for August.

Year.	0^h	1	2	3	4	5	6	7	8	9	10	11^h	Noon	13	14	15	16	17	18	19	20	21	22	23	Min.
1841	686		680		676		664		662		652		653		662		666		676		689		691		+17
1842	689		689		683		682		679		672		652		659		669		679		688		688		+17½
1843	703		703		708		706		698		683		669		671		672		682		695		699		+23½
1844	794	790	786	781	783	777	776	769	763	760	756	754	750	750	746	759	764	771	778	789	790	789	792	794	+23½
Means	718		715		712		706		700		691		681		686		693		704		715		718		+20.4

Normals of the Vertical Force for September.

Year.	0^h	1	2	3	4	5	6	7	8	9	10	11^h	Noon	13	14	15	16	17	18	19	20	21	22	23^h	Min.
1841	663		655		646		647		637		631		627		628		634		645		653		660		+17
1842	692		686		689		690		681		671		671		673		672		679		687		693		+17½
1843	721		719		721		716		707		706		693		692		692		703		714		710		+23½
1844	816	815	813	812	811	810	809	805	798	795	790	785	780	779	772	794	793	795	806	813	812	812	814	817	+23½
Means	723		718		717		715		706		699		693		693		698		708		717		719		+20.4

NORMALS OF THE VERTICAL FORCE FOR OCTOBER.

Year.	0^h	1	2	3	4	5	6	7	8	9	10	11^h
1841	579		578		573		568		558		556	
1842	706		698		702		714		695		708	
1843	714	710	707	713	712	714	717	714	706	704	703	701
1844	775	771	769	773	776	779	780	780	774	773	773	770
[1]Means.	694		689		691		694		684		685	

Noon	13	14	15	16	17	18	19	20	21	22	23^h	Min.
561		562		571		577		581		583		+17
707		706		706		708		710		709		+17½
702	700	703	701	704	709	714	717	719	715	714	717	+23½
769	766	773	777	786	788	791	789	785	785	781	781	+23½
685		685		692		697		699		697		+20.4

NORMALS OF THE VERTICAL FORCE FOR NOVEMBER.

Year.	0^h	1	2	3	4	5	6	7	8	9	10	11^h
1841	532		537		538		533		526		523	
1842	717		713		723		725		712		715	
1843	742	740	745	743	745	744	744	748	742	739	737	729
1844	775	772	768	769	772	771	770	773	768	772	772	767
Means	691		691		694		693		688		686	

Noon.	13	14	15	16	17	18	19	20	21	22	23^h	Min.
520		521		526		529		531		538		+17
711		713		716		712		718		718		+17½
735	731	731	738	746	749	749	751	749	747	746	748	+23½
766	763	762	765	774	779	777	778	774	770	769	772	+23½
682		683		690		692		693		693		+20.4

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[1] Let m equal any reading at an even hour in 1843 or 1844, mp and mf the same for the odd hours preceding and following, then mean for the even hour $\frac{1}{2}\left(m + \frac{mp + mf}{2}\right)$ which was substituted for the above value at the even hour in 1843 and 1844 before the general mean of the four years was taken.

NORMALS OF THE VERTICAL FORCE FOR DECEMBER.

Year.	0h	1	2	3	4	5	6	7	8	9	10	11h
1841	597		591		590		606		592		598	
1842	713		707		709		706		715		711	
1843	752	744	733	742	740	742	740	743	740	740	729	720
1844	754	753	754	755	757	756	755	758	749	751	750	746
Means	703		697		699		703		700		697	

Noon	13	14	15	16	17	18	19	20	21	22	23h	Min.
605		597		607		610		605		604		+17
709		707		706		711		713		713		+17½
727	729	743	749	758	760	767	763	764	757	754	757	+23½
743	733	736	724	748	757	755	751	751	748	750	750	+23½
695		695		704		710		707		705		+20.4

NORMALS OF THE VERTICAL FORCE FOR JANUARY.

Year.	0h	1	2	3	4	5	6	7	8	9	10	11h
1841												
1842	658		642		656		649		656		653	
1843												
1844	733	739	730	728	732	733	732	732	730	725	720	713
1845	754	747	747	752	752	757	763	767	760	758	753	752
Means	716		707		713		715		715		709	

Noon	13	14	15	16	17	18	19	20	21	22	23h	Min.
664		650		663		675		670		663		+17½
		[1]690										+17
715	708	715	724	737	740	741	743	744	745	744	744	+23½
751	748	749	742	753	760	756	753	749	746	747	754	+23½
709		705		717		724		721		719		+21.5

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[1] No use is made of this reading, nor of the analogous readings in the following two months.

Normals of the Vertical Force for February.

Year.	0^{h}	1	2	3	4	5	6	7	8	9	10	11^{h}
1841	664		664		662		656		654		650	
1842	706		701		713		721		699		698	
1843												
1844	734	729	725	726	729	728	729	730	723	724	722	717
1845	760	756	752	757	759	760	763	764	756	756	752	749
Means	718		711		716		717		709		705	

Noon	13	14	15	16	17	18	19	20	21	22	23^{h}	Min.
644		648		647		673		668		665		+17
709		692		698		712		723		710		+17½
		(697)										+17
718	716	716	720	727	731	738	739	740	737	735	733	+23½
747	741	740	744	753	759	761	761	758	753	752	756	+23½
704		700		706		720		722		716		+20.4

Normals of the Vertical Force for March.

Year.	0^{h}	1	2	3	4	5	6	7	8	9	10	11^{h}
1841	670		661		661		655		651		645	
1842	655		643		654		663		657		661	
1843												
1844	768	761	763	760	764	762	765	762	758	761	762	764
1845	749	741	736	742	746	748	749	746	736	733	732	729
Means	709		701		705		707		701		700	

Noon	13	14	15	16	17	18	19	20	21	22	23^{h}	Min.
643		646		656		665		666		673		+17
651		650		657		668		673		665		+17½
		(686)										+17
762	753	758	760	754	757	753	754	752	753	763	764	+23½
729	729	713	734	740	747	751	746	741	740	739	743	+23½
696		694		703		709		708		710		+20.4

Normals of the Vertical Force for April.

Year.	0h	1	2	3	4	5	6	7	8	9	10	11h
1841	671		662		658		653		645		646	
1842	668		658		655		655		656		654	
1843	715		712		717		716		708		702	
1844	776	773	771	765	766	765	759	755	749	749	744	740
1845	732	727	728	729	728	727	725	721	718	715	717	717
Means	712		706		705		702		696		693	

Noon	13	14	15	16	17	18	19	20	21	22	23h	Min.
646		649		656		666		670		676		+17
657		651		650		660		672		672		+17½
709		700		696		696		710		709		+23½
737	733	737	741	745	744	756	767	768	765	767	775	+23½
716	713	717	720	724	724	732	737	736	729	726	727	+23½
693		691		694		702		711		711		+21.0

Normals of the Vertical Force for May.

Year.	0h	1	2	3	4	5	6	7	8	9	10	11h
1841	669		665		660		654		647		649	
1842	673		670		661		644		646		647	
1843	698		699		695		690		682		680	
1844	772	769	766	768	767	764	760	754	749	747	747	744
1845	720	718	717	719	716	715	713	709	705	702	701	699
Means	706		704		700		692		686		685	

Noon	13	14	15	16	17	18	19	20	21	22	23h	Min.
644		646		650		660		674		679		+17
651		644		645		656		668		670		+17½
677		668		677		685		691		695		+23½
744	740	747	744	746	748	754	763	766	766	768	772	+23½
697	696	701	698	702	705	710	720	718	717	718	719	+23½
683		680		684		693		703		706		+21.0

NORMALS OF THE VERTICAL FORCE FOR JUNE.

Year.	0^{h}	1	2	3	4	5	6	7	8	9	10	11^{h}
1841	646		631		622		617		624		616	
1842	674		669		664		658		647		642	
1843	698		691		693		687		677		668	
1844	776	772	767	768	767	764	760	755	747	745	744	744
1845	733	731	729	730	729	728	726	722	717	715	715	711
Means	705		698		695		690		683		677	

Noon	13	14	15	16	17	18	19	20	21	22	23^{h}	Min.
603		624		635		650		653		657		+17
635		639		635		653		671		668		+17½
663		658		659		669		681		689		+23½
742	739	744	747	749	754	760	769	771	770	771	775	+23½
711	711	713	714	713	714	722	730	735	731	731	733	+23½
671		675		678		691		702		703		+21.0

TABLE I.—RECAPITULATION OF THE BI-HOURLY NORMALS OF THE VERTICAL FORCE (EXPRESSED IN SCALE DIVISIONS) FOR EACH MONTH OF THE YEAR.

Increase of scale readings denotes decrease of force.

1841–5.	0^{h}	2	4	6	8	10	Noon	14	16	18	20	22^{h}	$(+20^{m}.6)$
January	716	707	713	715	715	709	709	705	717	724	721	719	
February	718	711	716	717	709	705	704	700	706	720	722	716	
March	709	701	705	707	701	700	696	694	703	709	708	710	
April	712	706	705	702	696	693	693	691	694	702	711	711	
May	706	704	700	692	686	685	683	680	684	693	703	706	
June	705	698	695	690	683	677	671	675	678	691	702	703	
July	722	717	712	703	698	692	687	688	693	706	717	721	
August	718	715	712	706	700	691	681	686	693	704	715	718	
September	723	718	717	715	706	699	693	693	698	708	717	719	
October	694	689	691	694	684	685	685	685	692	697	699	697	
November	691	691	694	693	688	686	682	683	690	692	693	693	
December	703	697	699	703	700	697	695	695	704	710	707	705	
Year . .	709.7	704.5	704.9	703.1	697.2	693.2	689.9	689.6	696.0	704.7	709.6	709.8	
Summer .	714.3	709.7	706.8	701.3	694.8	689.5	684.7	685.5	690.0	700.7	710.8	713.0	
Winter .	705.2	699.3	703.0	704.8	699.5	697.0	695.2	693.7	702.0	708.7	708.3	706.7	

The months from April to September inclusive comprise the summer half year, those from October to March inclusive the winter half year.

TABLE II.—MEAN VALUES OF THE NORMALS FOR EACH MONTH AND SEASON.

1841–45.		1841–44.		1841–45.	
January	714.2	July	704.7		
February	712.0	August	703.3	Year	701.0
March	703.6	September	708.8	Summer	700.0
April	701.3	October	691.0	Winter	702.0
May	693.5	November	689.7		
June	689.0	December	701.2		

Subtracting each value of Table I from its respective monthly mean as given in Table II, and converting the remainder into parts of the force, we find the regular solar-diurnal variation presented in the following table:—

TABLE III.—REGULAR SOLAR-DIURNAL VARIATION OF THE VERTICAL FORCE EXPRESSED IN PARTS OF THE FORCE.

A plus sign indicates a greater, a minus sign a less value than the mean. The first three places of decimals 0.000 have been placed on the side.

	1841–5.	0h	2	4	6	8	10	Noon.	14	16	18	20	22h	+20m.6
0.000	January	—059	+238	+040	—026	—026	+172	+172	+304	—092	—323	—224	—158	
	February	—198	+033	—132	—165	+099	+231	+264	+396	+198	—264	—330	—132	
	March	—178	+086	—046	—112	+086	+119	+251	+317	+020	—178	—145	—211	
	April	—353	—155	—122	—023	+175	+274	+274	+340	+241	—023	—320	—320	
	May	—412	—346	—214	+049	+247	+280	+346	+445	+313	+016	—313	—412	
	June	—528	—297	—198	—033	+198	+396	+594	+462	+363	—066	—429	—462	
	July	—571	—406	—241	+056	+221	+419	+584	+551	+386	—043	—406	—538	
	August	—485	—386	—287	—089	+109	+406	+736	+571	+340	—023	—386	—485	
	September	—469	—304	—271	—205	+092	+323	+521	+521	+356	+026	—271	—337	
	October	—099	+066	—000	—099	+231	+198	+198	+198	—033	—198	—264	—198	
	November	—043	—043	—142	—109	+086	+122	+254	+221	—010	—076	—109	—109	
	December	—059	+139	+040	—059	+040	+139	+205	+205	—092	—290	—191	—125	
	Year	—287	—115	—131	—068	+129	+257	+366	+377	+165	—121	—282	—290	
	Summer	—469	—317	—221	—040	+175	+350	+508	+482	+333	—020	—353	—426	
	Winter	—106	+086	—040	—096	+082	+162	+224	+274	—000	—221	—211	—155	

Multiplying the above numbers by Y=12.83, we obtain the solar-diurnal variation in absolute value.

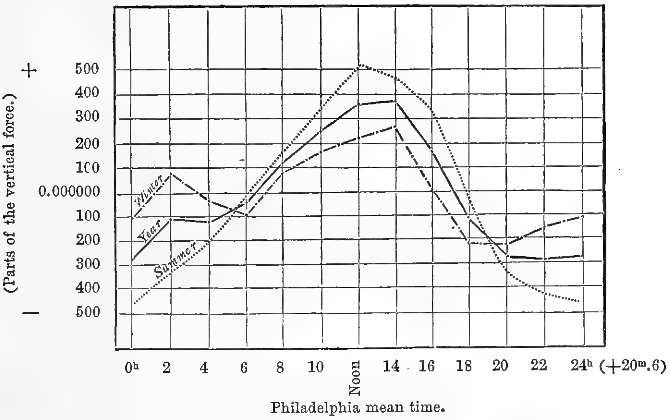
TABLE IV.—REGULAR SOLAR-DIURNAL VARIATION OF THE VERTICAL FORCE IN ABSOLUTE MEASURE.

A greater force than the mean is indicated by a plus sign, a less force by a minus sign. The first two places of decimals 0.00 are placed on the side.

	1841–5.	0h	2	4	6	8	10	Noon.	14	16	18	20	22h	+20m.6
0.00	January	—076	+305	+051	—034	—034	+220	+220	+389	—118	—415	—289	—203	
	February	—254	+042	—170	—212	+127	+296	+338	+508	+254	—338	—423	—169	
	March	—229	+110	—059	—144	+110	+152	+321	+406	+025	—228	—186	—271	
	April	—452	—198	—157	—030	+224	+351	+351	+436	+309	—030	—410	—410	
	May	—529	—444	—275	+064	+317	+360	+444	+571	+402	+021	—402	—529	
	June	—677	—380	—254	—042	+254	+508	+761	+592	+465	—085	—550	—592	
	July	—732	—520	—308	+072	+283	+537	+749	+706	+495	—055	—520	—690	
	August	—622	—495	—368	—114	+140	+520	+943	+732	+436	—030	—495	—622	
	September	—601	—389	—346	—263	+118	+415	+668	+668	+457	+034	—347	—431	
	October	—127	+085	—000	—127	+296	+254	+254	+254	—042	—254	—338	—254	
	November	—055	—055	—182	—140	+072	+157	+326	+283	—013	—098	—140	—140	
	December	—076	+178	+051	—076	+051	+178	+263	+263	—118	—372	—245	—161	
	Year	—368	—148	—168	—087	+165	+329	+470	+483	+212	—156	—364	—372	
	Summer	—601	—406	—284	—051	+224	+448	+651	+618	+426	—025	—453	—546	
	Winter	—136	+110	—051	—123	+106	+207	+288	+351	—000	—283	—271	—199	

Annual Inequality in the Diurnal Variation of the Vertical Force.—If we examine the average curve of the diurnal variation as observed throughout the year, and shown on diagram (A) by a full black line, we find the principal maximum value about 1 P. M., and the principal minimum value about 9½ P. M.; besides these characteristic values there is an indication of a secondary maximum about 2 A. M., and of a secondary minimum about 4 A. M. Dividing the year into a summer and winter season, the diagram exhibits the diurnal variation in summer to be a curve of but one maximum and one minimum occurring about noon and midnight respectively, whereas in winter the double feature of the curve becomes very conspicuous, the secondary maximum and minimum occurring about 2 and 6 A. M. respectively. The phenomenon, in the two seasons, changes therefore from a single to a double crested curve.

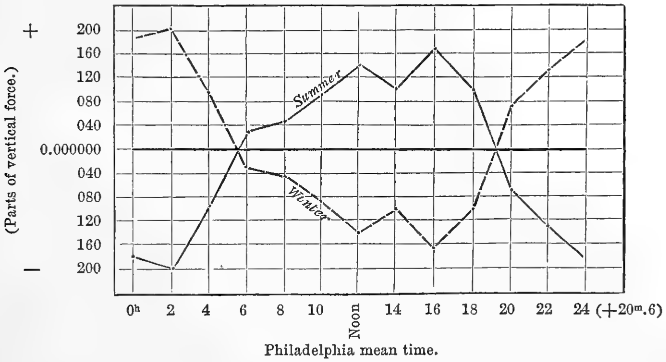
(A.) Diurnal Variation of the Vertical Force in Summer, Winter, and for the whole Year.



The semi-annual change of the diurnal variation is better shown in diagram (B), which contains the difference from the annual curve in summer and winter, viz. :—

	0h	2	4	6	8	10	Noon.	14	16	18	20	22h	(+20m.6)
Summer	—182	—201	—90	+28	+46	+93	+142	+105	+168	+101	—71	—136	
Winter	+181	+202	+91	—28	—47	—95	—142	—103	—165	—100	+71	+135	

(B.) Semi-Annual Inequality in the Diurnal Variation of the Vertical Force.



At $5\frac{1}{2}$ A. M. and 7 P. M. there is no change in the diurnal variation throughout the year; at the hours 2 A. M. and 4 P. M. the change is a maximum, viz: range equal 0.000403 parts and 0.000333 parts of the force, or equal 0.00517 and 0.00427 when expressed in absolute measure.

The turning epochs of the annual inequality as found from the hours 2 A. M. and 4 P. M. are derived from the following table, in which the numbers are expressed in parts of the force; the numbers in the last column were obtained by changing the sign of the afternoon difference before taking the mean.

	2 A. M. 0.000.	Differences. 0.000.	4 P. M. 0.000.	Differences. 0.000.	Mean difference. 0 000.
January	+238	+353	—092	—257	+305
February	+033	+148	+198	+033	+058
March	+086	+201	+020	—145	+173
April	—155	—040	+241	+076	—058
May	—346	—231	+313	+148	—190
June	—297	—182	+363	+198	—190
July	—406	—291	+386	+221	—256
August	—386	—271	+340	+175	—223
September	—304	—189	+356	+191	—190
October	+066	+181	—033	—198	+190
November	—043	+072	—010	—177	+125
December	+139	+254	—092	—257	+256
Mean	—115		+165		

The figures in the last column are represented by the equation

$$\Delta_a = + 0.000260\, sin\, (\theta + 86°) + 0.000031\, sin\, (2\,\theta + 180°)$$

the angle θ counting from January 1st at the rate of 30° a month. According to this expression the transition of the inequality from a positive to a negative value, and vice versa, takes place in the first quarter of April and October, or about 17 days after the equinoxes. The retardation of the phenomenon in the declination, horizontal and vertical force is, therefore, 10, 22, and 17 days respectively, or 16 days on the average.

Analysis of the Solar-Diurnal Variation of the Vertical Force.—For greater facility of the investigation, and for purposes of comparison, the numbers of Table I. have been expressed analytically. The angle θ counts from midnight at the rate of 15° an hour.

$$\begin{aligned}
&\text{For January,} && \Delta_v = 714^d.2 + 4.8\, sin\, (\theta + 134° 09') + 5.5\, sin\, (2\theta + 224° 22') \\
& && \qquad + 0.8\, sin\, (3\theta + 61°) \\
&\text{For February,} && \Delta_v = 712^d.0 + 7.5\, sin\, (\theta + 91° 47') + 5.1\, sin\, (2\theta + 226° 22') \\
& && \qquad + 1.6\, sin\, (3\theta + 273°) \\
&\text{For March,} && \Delta_v = 703^d.6 + 5.5\, sin\, (\theta + 98° 24') + 3.6\, sin\, (2\theta + 220° 22') \\
& && \qquad + 0.7\, sin\, (3\theta + 95°) \\
&\text{For April,} && \Delta_v = 701^d.3 + 10.5\, sin\, (\theta + 89° 12') + 2.2\, sin\, (2\theta + 175° 59') \\
& && \qquad + 1.3\, sin\, (3\theta + 232°) \\
&\text{For May,} && \Delta_v = 693^d.5 + 13.1\, sin\, (\theta + 85° 17') + 1.9\, sin\, (2\theta + 144° 31') \\
& && \qquad + 1.8\, sin\, (3\theta + 278°) \\
&\text{For June,} && \Delta_v = 689^d.0 + 15.8\, sin\, (\theta + 87° 22') + 3.1\, sin\, (2\theta + 193° 56') \\
& && \qquad + 0.4\, sin\, (3\theta + 210°)
\end{aligned}$$

For July, $\Delta_v = 704^d.7 + 17.4\ sin\ (\theta + 86^\circ\ 30') + 2.6\ sin\ (2\theta + 174^\circ\ 16')$
$+\ 0.7\ sin\ (3\theta + 300^\circ)$

For August, $\Delta_v = 703^d.3 + 17.1\ sin\ (\theta + 81^\circ\ 10') + 3.7\ sin\ (2\theta + 215^\circ\ 50')$
$+\ 0.5\ sin\ (3\theta + 75^\circ)$

For September, $\Delta_v = 708^d.8 + 14.3\ sin\ (\theta + 73^\circ\ 57') + 2.9\ sin\ (2\theta + 210^\circ\ 24')$
$+\ 0.3\ sin\ (3\theta + 165^\circ)$

For October, $\Delta_v = 691^d.0 + 6.1\ sin\ (\theta + 119^\circ\ 48') + 3.1\ sin\ (2\theta + 236^\circ\ 28')$
$+\ 1.1\ sin\ (3\theta + 210^\circ)$

For November, $\Delta_v = 689^d.7 + 4.4\ sin\ (\theta + 83^\circ\ 33') + 3.0\ sin\ (2\theta + 254^\circ\ 00')$
$+\ 0.0$

For December, $\Delta_v = 701^d.2 + 4.5\ sin\ (\theta + 133^\circ\ 49') + 4.3\ sin\ (2\theta + 231^\circ\ 57')$
$+\ 1.0\ sin\ (3\theta + 63^\circ)$

We have also for summer half year (April to September inclusive), for winter half year (October to March inclusive), and for the whole year the following expressions for the diurnal variation:—

For summer, $\Delta_v = 700^d.1 + 14.6\ sin\ (\theta + 83^\circ\ 40') + 2.5\ sin\ (2\theta + 191^\circ\ 01')$
$+\ 0.5\ sin\ (3\theta + 255^\circ)$

For winter, $\Delta_v = 702^d.0 + 5.1\ sin\ (\theta + 108^\circ\ 54') + 4.0\ sin\ (2\theta + 229^\circ\ 58')$
$+\ 0.0$

For year, $\Delta_v = 701^d.0 + 9.7\ sin\ (\theta + 90^\circ\ 17') + 3.0\ sin\ (2\theta + 216^\circ\ 22')$
$+\ 0.2\ sin\ (3\theta + 255^\circ)$

The following comparison may serve to show the general representation of the observations by the analytical expressions:—

COMPARISON FOR AUGUST.

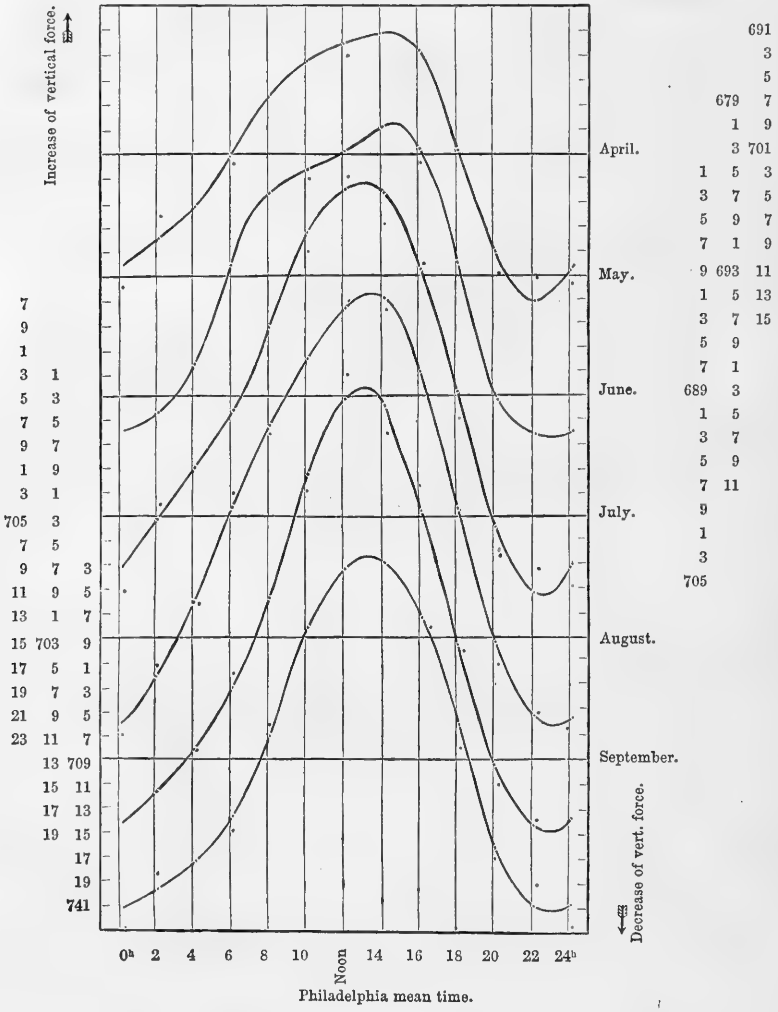
	Observed.	Computed.	Difference.
$0^h\ 20^m.6$	718	718.2	0
2 "	715	715.1	0
4 "	712	711.3	+1
6 "	706	707.0	—1
8 "	700	699.9	0
10 "	691	690.0	+1
12 "	681	683.0	—2
14 "	686	684.3	+2
16 "	693	693.5	0
18 "	704	705.0	—1
20 "	715	713.9	+1
22 "	718	718.4	0

The summer months are better represented than the winter months; in May the difference is below half a scale division; in the winter season in several instances it rises to 3, and in one case to 4 scale divisions.

Diagram C exhibits the diurnal variation, observed and computed, for the six summer months. Diagram D the same for the six winter months.

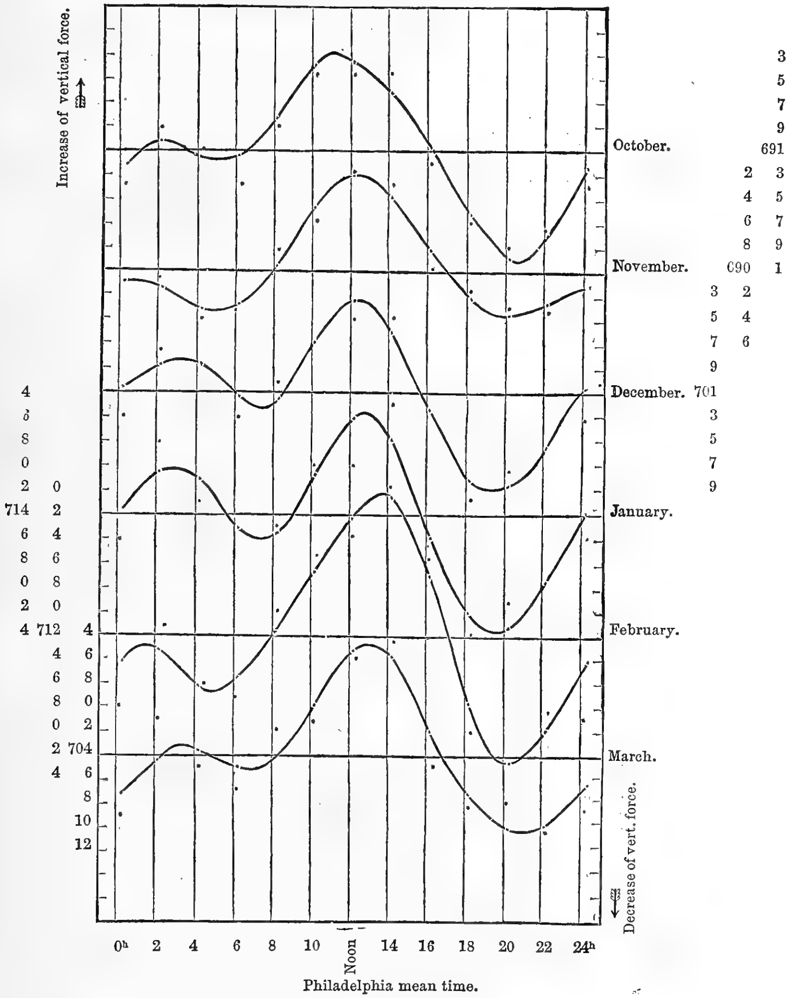
(C). SOLAR-DIURNAL VARIATION OF THE VERTICAL FORCE, APRIL TO SEPTEMBER, 1841 TO 1845.

(Expressed in scale divisions.)
$1^d = 0.000033$ parts of the force.



(D). Solar-Diurnal Variation of the Vertical Force, October to March, 1841 to 1845.

(Expressed in scale divisions.)
$1^d = 0.000033$ parts of the force.



The numerical values of the coefficients B_1 B_2 B_3 in the general equation

$$\Delta_v = A + B_1 \sin(\theta + C_1) + B_2 \sin(2\theta + C_2) + B_3 \sin(3\theta + C_3)$$

expressed in parts of the horizontal force, are given in Table V. The first three decimals (0.000) have been placed in front of the table.

TABLE V.

Month.		B₁	B₂	B₃
January	0.000	158	181	026
February		247	168	053
March		181	119	023
April		346	073	043
May		432	063	059
June		521	102	013
July		574	086	023
August		564	122	016
September		472	096	010
October		201	102	036
November		145	099	000
December		148	142	033
Summer		482	082	016
Winter		170	132	001
Year		320	099	007

The next table contains the numerical values of B_1 B_2 B_3 expressed in absolute measure, and the angles C_1 C_2 C_3 obtained by the addition of 180° to their preceding values, so as to make increasing values correspond to increasing force. The first two decimals for B are placed at the head of the columns.

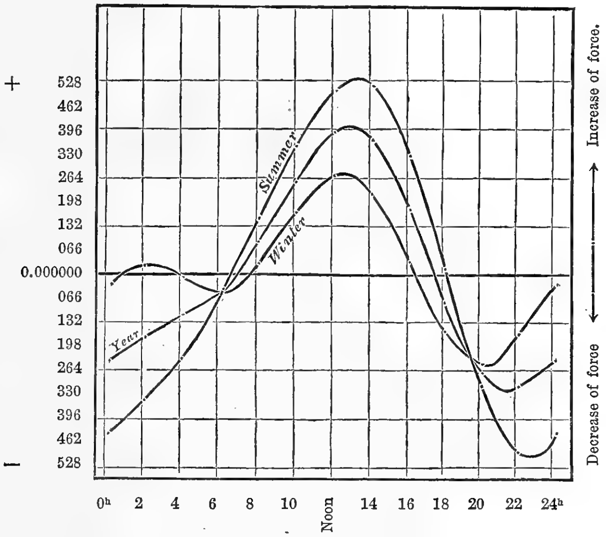
TABLE VI.

Month.	B₁ 0.00	C₁	B₂ 0.00	C₂	B₃ 0.00	C₃
January	203	314° 09′	233	44° 22′	034	241°
February	317	271 47	216	46 22	068	93
March	233	278 24	152	40 22	030	275
April	444	269 12	093	355 59	055	52
May	554	265 17	080	324 31	076	98
June	668	267 22	131	13 56	017	30
July	736	266 30	110	354 16	030	120
August	723	261 10	157	35 50	021	255
September	606	253 57	123	30 24	013	345
October	258	299 48	131	56 28	047	30
November	186	263 33	127	74 00	000	
December	190	313 49	182	51 57	042	243
Summer	618	263 40	106	11 01	021	75
Winter	218	288 54	169	49 58	002	
Year	410	270 17	127	36 22	008	75

The next diagram (E) exhibits the general feature of the diurnal inequality for the year and its summer and winter season, as computed by means of the preceding formulæ. The greatest difference between the observed and computed values at any one hour is but $2\frac{1}{3}$ scale divisions at 2 A. M. in the winter season, and $1\frac{1}{2}$ divisions at the same hour in the annual curve. The absence of the secondary wave in the early morning hours during summer is as conspicuous as its presence in the winter season; in the annual curve there is barely a trace of it left. We also recognize again the earlier occurrence of the maximum and minimum values in winter and their later appearance in summer. If we examine the resulting curves at Toronto[1] we find there the secondary morning fluctuation equally well marked in summer and winter; and if we inquire into this feature for each year separately, we find great irregularities between the hours 14 (Toronto astro'l time) and 22; in 1843 the secondary maximum and minimum is plainly developed, in 1844, and especially in 1845, it cannot be traced. Diagram (F) exhibits the curves for Philadelphia for each year. In 1841 and 1842 the curves are smooth, in 1843 the wave appears well marked, in 1844 it is just perceptible. These apparent irregularities are probably due to imperfections in our instruments; on the other hand, if we take the Philadelphia series, there may be a cyclic appearance and disappearance of this wave.

(E). Regular Solar-Diurnal Variation of the Vertical Force for Winter, Summer, and the whole Year.

(In parts of the force.)



Philadelphia mean time.

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[1] Vol. III of the Toronto Observations, Table LXVIII.

Diagram (F).

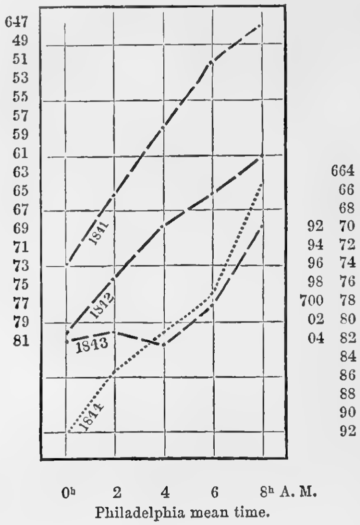


Table VII exhibits the computed times of the principal maximum and minimum of the vertical force, together with the amount of difference from its average daily value at these epochs, expressed in scale divisions; also the time and amount of the early morning secondary fluctuation traceable only in the winter months; for these last values the diagrams have been made use of.

Table VII.

	Maximum at	Amount in scale divisions.	Minimum at	Amount in scale divisions.	Time elapsed between max & min.	Secondary maximum at	Amount.	Secondary Minimum at	Am't.	Secondary range.
January	$13^h\ 07^m$	— $8^d.5$	$19^h\ 27^m$	+ $9^d.4$	$6^h\ 20^m$	$2\frac{1}{2}^h$	—4	7^h	+2	6
February	13 41	—11.5	20 21	+10.6	6 40	$1\frac{1}{2}$	+1	$4\frac{1}{2}$	+4	3
March	12 46	— 8.9	21 04	+ 6.7	8 18	3	—1	$6\frac{1}{2}$	+2	3
April	13 52	—10.2	22 04	+11.8	8 12	-----	----	-----	----	-----
May	14 34	—13.1	22 58	+12.6	8 24	-----	----	-----	----	-----
June	13 09	—17.2	22 35	+16.2	9 26	-----	----	-----	----	-----
July	13 33	—18.2	23 10	+17.3	9 37	-----	----	-----	----	-----
August	13 02	—20.8	23 06	+15.5	10 04	-----	----	-----	----	-----
September	13 23	—16.8	23 20	+12.6	9 57	-----	----	-----	----	-----
October	11 16	— 7.6	20 34	+ 8.7	9 18	2	—1	5	+1	2
November	12 35	— 7.4	19 59	+ 3.9	7 24	1	+1	$4\frac{1}{2}$	+3	2
December	12 31	— 7.8	19 09	+ 7.8	6 38	3	—3	7	+1	4
Summer	13 29	—15.8	22 55	+14.1	9 26	-----	----	-----	----	-----
Winter	12 43	— 8.2	20 08	+ 7.6	7 25	2	—1	6	+2	3
Year	13 02	—11.9	21 25	+ 9.7	8 23	-----	----	-----	----	-----

The extreme variation in the time of the maximum in the course of a year is $3^h\ 18^m$, and of the minimum $4^h\ 11^m$.

At Toronto the occurrence of the maxima and minima is later than at Philadelphia; from Table LXVIII, Vol. III of the Toronto Observations, we find the maximum at 5^h, a secondary minimum at 14^h, a secondary maximum at 18^h, and the minimum at 22^h; the maximum is therefore apparently delayed at Toronto 4^h, the minimum $4\frac{3}{4}^h$, the secondary wave is likewise retarded by about 4 hours. This epochal difference I take, most likely, to be a distinctive feature due to the localities; there is also a remarkable difference in the amount of the diurnal range as will presently appear. The degree of sensibility in the adjustment of the centre of gravity of the instrument affects most the latter difference, whereas the epochal difference may be supposed to depend, in a measure, upon the sensibility of the magnet in regard to changes of temperature and consequent changes of magnetism.

The change in the adopted value of the correction for 1° of change in the temperature (expressed in scale divisions) as used in present reduction (10.8), and as used in four volumes of record and reduction (13.5) gives us the means of a partial test of the effect on the epochs, we find from the plates in Vol. IV the time of the maximum 1½ P. M. and of the minimum 11½ P. M., which though somewhat nearer to the Toronto epochs, still leave a large discrepancy.

TABLE VIII.—AMPLITUDE OF THE DIURNAL VARIATION OF THE VERTICAL FORCE.

	Maximum 0.00	Minimum 0.00	Range 0.00	Maximum 0.00	Minimum 0.00	Range 0.0
January	028	031	059	359	398	0757
February	038	035	073	484	447	0931
March	029	022	051	377	283	0660
April	034	039	073	431	500	0931
May	043	042	085	555	535	1090
June	057	054	110	725	686	1411
July	060	057	117	769	733	1502
August	068	051	119	878	654	1532
September	055	041	097	712	532	1244
October	025	029	054	323	369	0692
November	024	013	037	313	166	0479
December	026	026	052	330	332	0662
Summer	052	046	098	667	597	1264
Winter	027	025	052	349	322	0671
Year	039	032	071	503	410	0913
	In parts of the force.			In absolute measure.		

The diurnal range at Toronto is very much less than at Philadelphia; in 1841–42 the range was but one-half of that observed at Philadelphia, and for later years (see Table LXVIII of Vol. III of the Toronto Observations) the ranges compare as follows: Toronto 0.00019, Philadelphia 0.00071.

In diagram G the diurnal range for each month is exhibited (expressed in parts of the force).

(G). Diurnal Range of the Vertical Force.

(In parts of the force.)

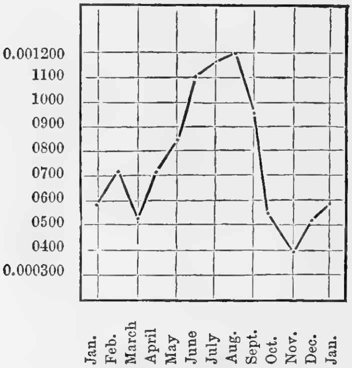


Table IX contains the times when the mean value of the vertical force is reached each day—arranged for monthly averages. In some months the average daily value is attained four times, but generally only twice. The table contains the two principal epochs (one A. M. the other P. M.); those produced by the secondary wave can easily be made out by means of the preceding diagrams.

Table IX.—Principal Epochs of Mean Vertical Force.

	A. M.	P. M.
January	8h 58m	3h 47m
February	7 42	5 16
March	8 27	4 53
April	6 15	6 13
May	5 55	6 21
June	6 36	6,04
July	6 08	6 10
August	7 30	6 04
September	7 51	6 28
October	6 34	4 19
November	8 11	4 49
December	8 27	3 39
Summer	6 43	6 13
Winter	7 52	4 29
Year	7 06	5 33

The next table contains the computed diurnal variation of the vertical force, expressed in absolute measure; compared with Table IV, it shows the differences between the observed and computed values.

Table X.—Computed Solar-Diurnal Variation of the Vertical Force, expressed in Absolute Measure.

The first two places of decimals 0.00 are placed on the side; + indicates more, — less than the monthly average.

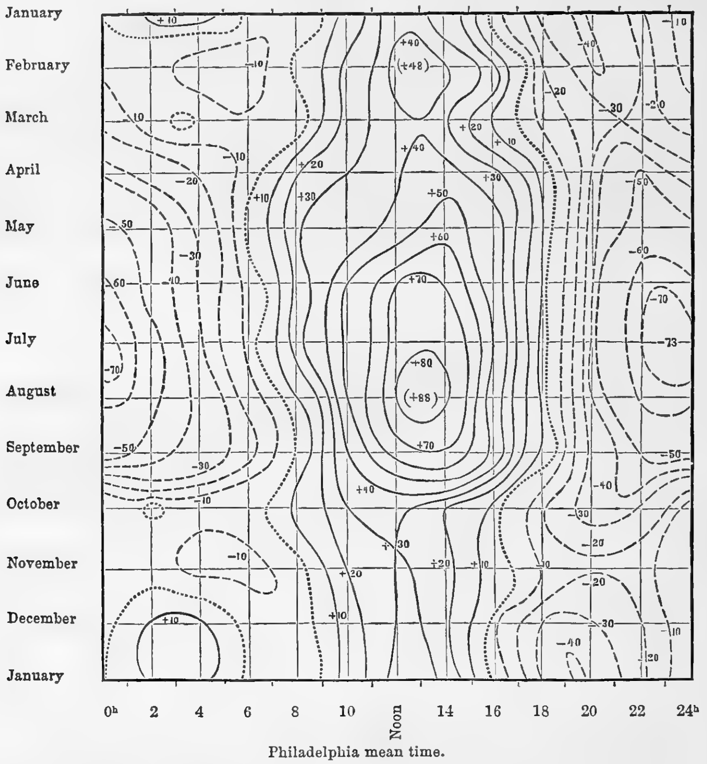
	1841–45.	0h	2	4	6	8	10	Noon.	14	16	18	20	22h	+20m.6
0.00	January	+025	+165	+123	—030	—046	+161	+355	+258	—080	—351	—376	—203	
	February	—072	—085	—178	—123	+063	+258	+436	+465	+203	—241	—444	—283	
	March	—135	—017	—008	—072	—013	+207	+372	+304	+059	—165	—275	—258	
	April	—385	—266	—165	+008	+216	+338	+402	+436	+317	—025	—385	—491	
	May	—516	—461	—262	+068	+309	+372	+448	+554	+423	—000	—402	—533	
	June	—601	—419	—245	—042	+241	+533	+711	+681	+398	—068	—503	—685	
	July	—706	—550	—279	+034	+305	+537	+723	+744	+457	—051	—499	—714	
	August	—630	—499	—338	—157	+144	+563	+859	+804	+414	—072	—448	—639	
	September	—512	—431	—351	—207	+076	+431	+673	+677	+436	+047	—321	—516	
	October	—055	+030	—030	—008	+165	+309	+300	+182	—004	—237	—377	—275	
	November	—059	—089	—148	—131	+017	+207	+313	+233	+046	—123	—161	—106	
	December	—008	+110	+097	—008	—008	+182	+330	+203	—114	—313	—304	—165	
	Year	—309	—211	—152	—055	+123	+343	+495	+457	+211	—131	—368	—402	
	Summer	—558	—440	—275	—050	+212	+465	+634	+651	+410	—025	—423	—600	
	Winter	—046	+017	—021	—051	+034	+216	+338	+271	+021	—228	—321	—216	

A graphical representation of the above tabular numbers is given in diagram H, based upon the three variables: the hour of the day, the month, and the difference of vertical force from the normal monthly value. The contour lines of the magnetic surface differ 0.001 of vertical force (in absolute measure). Full lines indicate greater value, lines of dashes less value than the normal, dotted lines represent the normal value.

(H). Differences from its Normal Value of the Vertical Force, for each Hour and Month.

(Expressed in absolute measure.)

0.00.



Annual Inequality of the Vertical Force.—The minor and irregular disturbances in the adjustment of the magnetometer, as well as the effect of the progressive and secular changes, tend to make the determination of the annual inequality in the vertical force a task of some delicacy, and the results deduced from our series of observations should be considered as approximate.

Taking the monthly normals of the years 1842, 1843, and 1844, the only years which could be made complete, and correcting the monthly means for 42 scale divisions of annual increase, the following table was formed:—

MONTHLY NORMALS.

Year.	January.	Feb'u'ry.	March.	April.	May.	June.	July.	August.	Sept'ber.	October.	Nov'ber.	Dec'ber.
1842 . . .	658	707	658	659	656	655	662	677	682	706	716	710
1843 . . .	702	710	691	707	686	678	677	691	708	710	742	746
1844 . . .	731	728	760	756	756	758	796	773	801	778	770	749
Mean . . .	697	715	703	707	699	697	712	714	730	731	743	735
Corr'd . .	+19	+16	+12	+ 9	+ 5	+ 2	— 2	— 5	— 9	—12	—16	—19
Corr'd m. . .	716	731	715	716	704	699	710	709	721	719	727	716
Mean monthly val.	— 1	—16	0	— 1	+11	+16	+ 5	+ 6	— 6	— 4	—12	— 1

The vertical force appears, therefore, to be greater in May, June, July, and August, and less in the remaining months; the range is about 32 scale divisions $=0.00105$ parts of the force, or 0.0135 in absolute measure.

PART IX.

INVESTIGATION

OF THE

LUNAR INFLUENCE ON THE MAGNETIC VERTICAL FORCE, INCLINATION, AND TOTAL FORCE.

INVESTIGATION

OF THE

INFLUENCE OF THE MOON ON THE MAGNETIC VERTICAL FORCE.

THE method of discussion of the lunar effect on the vertical component of the magnetic force in no way differs from that employed for the horizontal component, which latter has been explained in Part VI.

The series of observations available for the lunar discussion extends from February, 1841, to June, 1845, inclusive. From February, 1841, to October, 1843, the observations are bi-hourly; from October, 1843, to the end of the series they are hourly. The record of May, 1841, is not quite complete, and in January, February, and March, 1843, but one observation a day is recorded. As increasing numbers denote a decrease of force, a positive sign of the tabulated differences between monthly normals and each individual undisturbed reading (at the normal temperature) indicates a greater force than the normal value, a negative sign indicates the reverse. 30 scale divisions being the limit beyond which difference an observation has been considered as belonging to the class of disturbances, all differences here recorded are below this limit. One scale division is 0.000033 parts of the force. The tabular numbers are expressed in scale divisions.

In tracing out the lunar effect upon the vertical force we have to contend with greater irregularities than was experienced in the case of the horizontal force. The vertical force magnetometer is more subject to changes, and the correction for temperature far exceeds that of the horizontal force.

The total number of observations and differences formed in the inquiry of the dependence of the force upon the moon's hour angle is 19513, which distribute themselves over the months and years as follows:—

TABLE I.—NUMBER OF OBSERVATIONS FOR LUNAR DISCUSSION.

Month.	1841.	1842.	1843.	1844.	1845.	Sum.
January	---	207	---	544	611	1362
February	239	198	---	549	554	1540
March	257	286	---	502	539	1584
April	256	255	250	512	581	1854
May	207	246	288	617	602	1960
June	219	275	296	529	571	1890
July	258	281	308	581	---	1428
August	283	284	314	535	---	1416
September	267	246	292	568	---	1373
October	280	298	580	607	---	1765
November	275	299	528	596	---	1698
December	239	304	541	559	---	1643
Year	2780	3179	3397	6699	3458	19513

TABLE II.—DISTRIBUTION OF NUMBERS ACCORDING TO WESTERN AND EASTERN HOUR ANGLES OF THE MOON.

Year.	Western hour angles.	Eastern hour angles.
1841	1388	1392
1842	1588	1591
1843	1694	1703
1844	3321	3378
1845	1728	1730
Sum	9719	9794

TABLE III.—DIFFERENCES FROM THE MONTHLY NORMALS, 1841.

Western hour angles of the moon.

1841.	U. cul. 0^h	1	2	3	4	5	6	7	8	9	10	11^h
January	- - - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
February	+3	+1	+3	—2	+8	—5	0	+1	—1	+4	—2	—3
March	—6	+5	—3	+6	+1	+9	—6	+2	—7	—1	—3	0
April	—1	+1	0	+2	—1	+3	—1	0	—1	+7	—7	+2
May	+5	—1	+2	+1	+4	+7	+3	+4	+4	+1	+5	—5
June	0	—6	—5	+2	—8	—2	+5	—3	—4	+8	+7	0
July	—4	+8	—6	+2	—7	+5	—3	+1	—1	—7	+5	—4
August	—1	—5	+1	—6	—5	—6	0	—1	0	+1	—3	—1
September	+3	+3	+1	+1	—6	+5	—2	+2	0	—4	—3	—3
October	—8	—1	—2	0	—2	—1	—4	0	+1	0	+6	+4
November	—3	+3	—1	+3	—3	—3	—6	—5	+1	—3	+4	—1
December	—5	—4	0	—1	—2	—5	—3	—3	+5	+2	—3	—2
Year	—1.5	+0.4	—0.9	+0.7	—2.0	+0.6	—1.5	—0.2	—0.3	+0.7	+0.5	—1.2

Eastern hour angles.

1841.	L. cul. 0	1	2	3	4	5	6	7	8	9	10	11^h
January	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
February	—3	—2	+1	—3	+3	—2	+4	—3	+3	+2	+2	—1
March	0	+2	+3	+7	—1	+8	—7	+1	—8	0	—6	+1
April	0	—4	0	—1	0	—2	—1	—3	—1	—1	—1	+1
May	—2	—2	+1	—6	+1	—5	+1	—8	+3	—10	+3	—4
June	+1	+5	—2	+1	+5	—7	+5	+3	—1	—6	—2	—8
July	+1	—4	+6	0	—2	+5	—2	+5	—2	+2	—2	+7
August	+1	—1	+2	0	0	+1	+4	+5	+2	+4	+1	+3
September	—3	+2	—4	0	—1	+2	—1	—2	+1	0	+2	+8
October	+3	+4	+4	—1	+1	+1	+4	—1	+2	—2	—4	—4
November	+2	—3	+1	0	—1	+5	—3	+5	0	+8	—2	+2
December	+6	+6	+1	+6	+3	+2	+3	—10	0	—10	0	—7
Year	+0.5	+0.3	+1.2	+0.3	+0.7	+0.7	+0.6	—0.7	—0.1	—1.2	—0.8	—0.2

TABLE IV.—DIFFERENCES FROM THE MONTHLY NORMALS, 1842.

Western hour angles of the moon.

1842.	U. cul. 0	1	2	3	4	5	6	7	8	9	10	11h
January	—6	0	—1	—7	—6	—5	+4	+8	—3	+9	+4	+7
February	—3	0	+5	—6	+4	—3	—9	—11	+6	+3	+7	+6
March	+5	+2	+3	0	+2	—4	—6	—6	+4	—1	—5	+5
April	+2	+2	0	0	—11	—2	—5	—3	—7	—1	+1	—5
May	—5	+3	—3	+2	—3	+4	0	0	+5	—2	+3	—7
June	+3	+5	+3	+2	—2	+1	+3	—3	+8	—7	+6	—7
July	—2	—4	—3	+2	—6	—2	0	+2	+4	+3	+7	+1
August	+2	—2	+1	—4	0	+1	—3	—2	+1	—1	+8	—3
September	+3	—5	—2	—7	—5	—3	+3	—1	—3	+6	—4	+5
October	0	0	—3	+4	+1	—5	+4	—1	+1	+4	—3	0
November	—3	+1	+1	—3	+2	+2	+3	0	+1	—4	+2	0
December	—1	—3	+1	+4	—4	+4	—1	+1	+4	—1	—3	+3
Year	—0.4	—0.1	+0.2	—1.1	—2.3	—1.0	—0.6	—1.3	+1.8	+0.7	+2.0	+0.4

Eastern hour angles.

1842.	L. cul. 0	1	2	3	4	5	6	7	8	9	10	11h
January	+5	+4	—3	—1	—5	—3	—2	+3	—4	+4	0	—4
February	+6	+1	—2	+4	—3	+3	—1	—7	—1	+9	—5	+3
March	—4	+3	—4	—3	—4	—6	+2	—4	+2	+2	0	+4
April	—3	+4	—1	+6	+3	+10	+1	+4	+1	0	+6	+2
May	+5	+2	+6	—4	0	—2	—2	—1	—12	+8	—8	+3
June	0	—6	0	—8	+3	—5	—3	—9	+3	—5	+3	—5
July	+2	+1	+2	+1	—3	—1	+1	—2	—1	0	—3	—1
August	+5	—3	—1	0	+1	0	+2	0	+2	0	+7	—3
September	—6	—2	—1	+2	—1	—1	+2	+9	+2	+12	+4	—3
October	—9	+1	—4	—3	0	—3	+2	+2	+2	+2	0	+2
November	+3	—1	—6	—2	—2	0	+2	+2	+1	+3	—1	0
December	+5	—1	—2	—1	—1	0	0	0	—5	+1	—3	—3
Year	+0.8	+0.2	—1.3	—0.8	—1.0	—0.7	+0.3	—0.3	—0.8	+3.0	0.0	—0.4

TABLE V.—DIFFERENCES FROM THE MONTHLY NORMALS, 1843.

Western hour angles of the moon.

1843.	U. cul. 0	1	2	3	4	5	6	7	8	9	10	11ʰ
January	---	---	---	---	---	---	---	---	---	---	---	---
February	---	---	---	---	---	---	---	---	---	---	---	---
March	---	---	---	---	---	---	---	---	---	---	---	---
April	+10	−3	+14	−5	+8	+1	0	+1	−5	+3	−2	−3
May	+6	−3	+4	+3	+3	−3	−3	−5	−1	−4	+1	−5
June	+1	−1	−4	+2	+2	+2	+1	+2	+1	+3	+4	+4
July	+7	+5	+4	+5	+4	+8	+3	+3	+3	+1	−1	−1
August	0	−2	+2	−1	+4	0	+5	−3	+3	−4	+2	−2
September	−3	+8	0	+5	−3	+4	+4	−7	+3	−3	+1	−3
October	+2	+2	+3	+3	+2	+2	−1	−4	−2	−3	−2	−3
November	+1	+2	+2	−3	+1	−2	−1	+1	0	+1	+4	0
December	+1	+2	+3	−2	0	+2	+2	+1	−1	0	+1	−2
Year	+2.4	+1.3	+3.0	+0.4	+2.0	+1.3	+0.8	−1.1	−0.2	−0.6	+0.9	−1.7

Eastern hour angles.

1843.	L. cul. 0	1	2	3	4	5	6	7	8	9	10	11ʰ
January	---	---	---	---	---	---	---	---	---	---	---	---
February	---	---	---	---	---	---	---	---	---	---	---	---
March	---	---	---	---	---	---	---	---	---	---	---	---
April	−2	0	−1	−6	−5	−6	+5	+1	+4	0	−2	+1
May	−2	−6	−3	0	+2	−1	+1	+2	+4	+2	+6	+2
June	+2	0	+1	+2	−1	+2	−2	+1	−1	0	+2	−2
July	−5	−4	−5	−5	−3	−5	−6	−3	+2	+1	+3	+4
August	+2	−2	0	−1	−1	−1	+5	−2	+2	−4	+4	+2
September	−2	0	−3	−1	−6	−3	−2	+4	+3	+1	−2	+4
October	−5	−1	+1	+1	0	0	0	0	0	+2	+3	0
November	−1	0	−3	+1	+3	−1	−1	−3	−1	+2	−2	+1
December	−2	0	−2	−1	−3	−2	−3	−3	−3	−2	−3	0
Year	−1.9	−1.2	−1.6	−0.9	−1.2	−1.7	−0.6	−0.8	+0.5	0.0	+0.6	+1.1

In making up the annual means, the October, November, and December values have received double weight; they are derived from double the number of observations.

TABLE VI.—DIFFERENCES FROM THE MONTHLY NORMALS, 1844.

Western hour angles of the moon.

1844.	U. cul. 0	1	2	3	4	5	6	7	8	9	10	11ʰ
January	+1	+5	0	0	—2	—1	—2	—1	—1	—1	—1	0
February	—1	—1	+1	+1	0	—1	+3	+3	0	+1	—1	—3
March	—4	—5	+2	—1	+3	—1	+1	—2	+1	—1	0	—3
April	+1	—1	+5	+2	0	+1	—4	+3	+3	0	—2	—3
May	0	+1	+1	+1	+1	+2	+3	+2	+2	+1	+2	0
June	+1	—2	—2	—2	—2	—1	—2	0	0	+3	0	+3
July	+2	+2	+2	+1	+1	+3	0	0	—2	0	0	0
August	+1	—2	—2	—2	—1	—2	—2	—6	—2	—4	—1	0
September	+1	+1	+1	—1	—1	—1	—2	0	—2	—2	—3	0
October	0	0	0	—2	—1	—3	—2	—3	—3	—2	0	+3
November	+2	+5	+5	+3	+2	0	+1	+3	+1	0	—2	—3
December	—1	0	+1	+3	0	—1	—1	—1	+2	+1	0	0
Year	+0.3	+0.3	+1.2	+0.3	0.0	—0.4	—0.6	—0.2	—0.1	—0.3	—0.7	—0.5

Eastern hour angles.

1844.	L. cul. 0	1	2	3	4	5	6	7	8	9	10	11ʰ
January	—1	—4	—2	—3	—2	—2	—3	0	+1	—2	—1	+3
February	—3	—1	+2	+1	0	—3	—4	—2	+1	—1	—1	0
March	—6	+1	—4	—2	—1	+4	+2	+5	+2	—4	—4	—1
April	—1	+1	+1	0	—1	—1	—3	—1	0	—1	—1	+2
May	—1	—2	0	—2	—2	—1	—3	—2	—2	—1	0	0
June	+1	0	+1	+1	0	+1	+2	—2	—1	+2	0	—1
July	+1	0	0	+1	0	—1	+1	+2	+1	0	+1	+1
August	—2	—1	—1	0	+2	+6	+4	+4	+3	+2	+1	—1
September	—1	—2	—1	—1	0	0	+2	+3	+2	+1	+4	+4
October	+4	+1	+1	+1	0	+2	+1	+1	0	+3	+1	+3
November	—4	—4	—1	+1	+1	+1	+2	+1	0	+1	+3	+2
December	+2	+2	+1	+2	0	+1	—3	—3	—1	—1	+2	—1
Year	—1.0	—0.8	—0.2	—0.1	—0.3	+0.6	—0.2	+0.5	+0.5	—0.1	+0.4	+1.0

TABLE VII.—DIFFERENCES FROM THE MONTHLY NORMALS, 1845.

Western hour angles of the moon.

1845.	U. cul. 0	1	2	3	4	5	6	7	8	9	10	11ʰ
January	+1	+2	+2	+2	+2	+4	+1	+1	—2	0	+3	+2
February	—2	0	—3	—2	—2	—2	0	0	+1	0	—1	+1
March	0	—1	—2	+1	+1	0	+2	+1	—2	0	+4	—1
April	—2	—4	—2	0	—1	—1	0	+2	+5	+4	+4	+2
May	—1	+1	+2	+1	+2	+3	—2	—1	0	+1	—1	0
June	+1	+1	+2	0	—2	0	—1	—1	—3	—4	—3	—2
Mean	—0.5	—0.2	—0.2	+0.3	0.0	+0.7	0.0	+0.3	—0.2	+0.2	+1.0	+0.3

Eastern hour angle.

1845.	L. cul. 0	1	2	3	4	5	6	7	8	9	10	11ʰ
January	0	—1	—5	—3	0	—1	0	—2	—2	—4	—3	0
February	+2	+3	+3	+3	+2	0	0	—1	0	—1	—2	0
March	+4	+2	—1	+2	—2	+1	—1	+1	—2	—2	—3	—3
April	—1	+1	—1	—1	—2	—2	—1	—1	0	+1	+1	+1
May	—1	—1	—2	—3	—2	—1	—1	0	+1	+1	0	—1
June	—1	+1	0	+1	+2	+1	+2	+2	+1	+3	+2	+3
Mean	+0.5	+0.9	—1.0	—0.2	—0.3	—0.3	—0.2	—0.2	—0.3	—0.3	—0.9	0.0

Before we combine the above results of years and parts of years, it is desirable to inquire into the variability of the lunar effect in summer and winter. Considering the months from April to September (inclusive) as summer months, and those from October to March (inclusive) as winter months, and combining the differences from the monthly normals in each year according to the number of observations, we obtain the following results:—

TABLE VIII.—LUNAR-DIURNAL VARIATION IN SUMMER AND WINTER, 1841 TO 1845.

(Expressed in scale divisions.)

Western hour angles.

	U. cul. 0	1	2	3	4	5	6	7	8	9	10	11ʰ
Summer	+1.0	—0.1	+0.6	+0.2	—1.0	+0.8	—0.4	—0.4	+0.1	—0.1	+0.6	—1.0
Winter	—0.8	+0.8	+0.9	+0.1	+0.4	—0.6	—0.5	—0.5	0.0	+0.1	+0.4	0.0

Eastern hour angles.

	L. cul. 0	1	2	3	4	5	6	7	8	9	10	11ʰ
Summer	—0.5	—0.8	—0.3	—0.9	—0.4	—0.4	+0.4	+0.4	+0.6	+0.6	+1.1	+0.8
Winter	—0.2	+0.3	—0.9	+0.3	+0.4	+0.2	—0.5	—0.7	—0.5	0.0	—1.1	0.0

These numbers are sufficiently irregular to indicate that we cannot hope to deduce any separate results for the seasons, the number of observations (about 9800) being altogether insufficient. We can therefore in our general combination of the annual means give equal weight to the results from the six months of hourly observations in 1845, and to the results from the twelve months of bi-hourly observations in 1842; compared with these results, those of 1844 have the weight two.

Table IX.—Recapitulation of the Annual Means exhibiting the Lunar-Diurnal Variation from over 19,500 Observations between February, 1841, and June, 1845, inclusive.

Western hour angles.

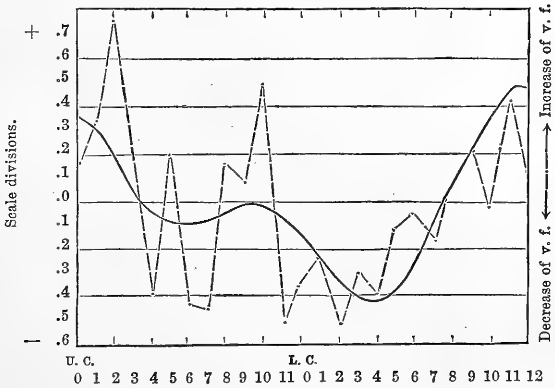
Weight.	Year.	U. cul. 0^h	1	2	3	4	5	6	7	8	9	10	11^h
1	1841	—1.5	+0.4	—0.9	+0.7	—2.0	+0.6	—1.5	—0.2	—0.3	+0.7	+0.5	—1.2
1	1842	—0.4	—0.1	+0.2	—1.1	—2.3	—1.0	—0.6	—1.3	+1.8	+0.7	+2.0	+0.4
1	1843	+2.4	+1.3	+3.0	+0.4	+2.0	+1.3	+0.8	—1.1	—0.2	—0.6	+0.9	—1.7
2	1844	+0.3	+0.3	+1.2	+0.3	0.0	—0.4	—0.6	—0.2	—0.1	—0.3	—0.7	—0.5
1	1845	—0.5	—0.2	—0.2	+0.3	0.0	+0.7	0.0	+0.3	—0.2	+0.2	+1.0	+0.3
	Mean	+0.10	+0.33	+0.75	+0.15	—0.38	+0.20	—0.42	—0.45	+0.15	+0.07	+0.50	—0.53

Eastern hour angles.

Weight.	Year.	L. cul. 0^h	1	2	3	4	5	6	7	8	9	10	11^h
1	1841	+0.5	+0.3	+1.2	+0.3	+0.7	+0.7	+0.6	—0.7	—0.1	—1.2	—0.8	—0.2
1	1842	+0.8	+0.2	—1.3	—0.8	—1.0	—0.7	+0.3	—0.3	—0.8	+3.0	0.0	—0.4
1	1843	—1.9	—1.2	—1.6	—0.9	—1.2	—1.7	—0.6	—0.8	+0.5	0.0	+0.6	+1.1
2	1844	—1.0	—0.8	—0.2	—0.1	—0.3	+0.6	—0.2	+0.5	+0.5	—0.1	+0.4	+1.0
1	1845	+0.5	+0.9	—1.0	—0.2	—0.3	—0.3	—0.2	—0.2	—0.3	—0.3	—0.9	0.0
	Mean	—0.35	—0.23	—0.52	—0.30	—0.40	—0.13	—0.05	—0.17	+0.05	+0.22	—0.05	+0.42

If we represent these values graphically, we find the general shape of the curve to be similar to that of the horizontal component, it is double crested with a principal maximum a little before the upper culmination, and a principal minimum about 3½ hours after the lower culmination of the moon; the average epoch of the vertical force tide is, therefore, about one and a half hours apparently in advance of the culminations. The secondary wave is very feeble, its greatest value

(A.) Lunar-Diurnal Variation of the Vertical Force, 1841 to 1845.



happens about 9^h, western hour angle, and its least value about three hours before, giving a range of nearly one-tenth part of the principal range. The observed values for the hours 8, 9, 10 (west) however, seem to indicate that the secondary wave is really larger, but in the present case apparently reduced by the accidentally low values at the hours 11 and 12.

The following expression has been deduced to express the lunar-diurnal variation of the vertical force:—

$$V_{☾} = -0.04 + 0.27 \sin (\theta + 72°) + 0.20 \sin (2\theta + 134°)$$

θ counts from the upper culmination, westward; $V_{☾}$ is expressed in scale divisions. The smooth, full curve in the diagram is computed by the formula; the differences between the observed and computed values are sufficiently well exhibited in the diagram. The probable error of any single hourly value is ± 0.20 scale divisions.

In the following expression M signifies millionth parts of the force:—

$$V_{☾} = -\overset{M}{1.3} + \overset{M}{8.9} \sin (\theta + 72°) + \overset{M}{6.6} \sin (2\theta + 134°).$$

Maximum value of $V_{☾}$, 28^m before the upper culmination, $= +.38$ scale divisions; minimum value at $15^h\ 30^m$, -0.43 scale divisions, hence lunar-diurnal range 0.81 scale divisions $= 0.000027$ parts of the force $= 0.00034$ in absolute measure. This range is so small that the correction for temperature due to a change of but 0°.08 would surpass it.

We have already seen that we cannot bring a sufficient number of observations to bear upon any *part* of the entire series, and are therefore not in a condition to pursue this subject of the lunar effect to any greater length.

At Toronto the curve is also double-crested with maxima three and a half hours after the moon's transits, but compared with Philadelphia the principal and secondary waves appear exchanged. The range at Toronto is 0.000012 parts of the force, nearly one-half of the Philadelphia range; we have already noticed a similar difference of range in the solar-diurnal variation, the Toronto range of which was also about one-half of that at Philadelphia. In connection with this it may be well to state that the dip at Toronto is 75° 15′, and at Philadelphia 71° 59.′

Lunar Effect upon Inclination and Total Force.—The combination of the horizontal and vertical components to inclination and total force, is effected by the formulæ:—

$$\Delta\theta = \sin\theta \cos\theta \left(\frac{\Delta Y}{Y} - \frac{\Delta X}{X}\right)$$

$$\frac{\Delta\phi}{\phi} = \cos^2\theta \frac{\Delta X}{X} + \sin^2\theta \frac{\Delta Y}{Y}$$

in which expressions $X =$ horizontal force, $Y =$ vertical force, $\phi =$ total force, and $\theta =$ inclination. The discussion of the observations for dip, in Part XII, gives the value $\theta = 71° \ 59'$, answering to the year 1843. Column 2 of the following table is derived from the preceding Table IX, after changing the scale divisions into their equivalents of parts of the force, one division being equal to 0.000033; column 3 is formed similarly from Table VIII, of Part VI, one division being equal to 0.0000365. Columns 4 and 5 contain the corresponding values of the lunar-diurnal variation of the inclination and total force, the former expressed in seconds, the latter in parts of the total force. The letter M, heading columns 2, 3, and 5, signifies units of the sixth place of decimals or millionth parts of the force.

TABLE X.—LUNAR-DIURNAL VARIATION OF THE INCLINATION AND TOTAL FORCE.

☾'s hour angle.	$\frac{\Delta Y}{Y}$	$\frac{\Delta X}{X}$	$\Delta\theta$	$\frac{\Delta\phi}{\phi}$
	M.	M.	$''$	M.
U. C.	+ 3.3	+11.0	—0.5	+ 4.0
1	+10.9	+18.2	—0.4	+11.6
2	+24.7	+32.8	—0.5	+25.4
3	+ 5.0	+40.1	—2.1	+ 8.3
4	—12.5	+ 7.3	—1.2	—10.6
5	+ 6.6	+25.5	—1.1	+ 8.4
6	—13.9	0.0	—0.9	—12.6
7	—14.8	+ 3.6	—1.1	—13.0
8	+ 5.0	—21.9	+1.6	+ 2.4
9	+ 2.3	—14.6	+1.0	+ 0.7
10	+16.5	— 7.3	+1.4	+14.2
11	—17.5	+ 3.6	—1.3	—15.4
L. C.	—11.6	+25.5	—2.2	— 8.1
1	— 7.6	+ 7.3	—0.9	— 6.2
2	—17.2	+14.6	—1.9	—14.1
3	— 9.9	—11.0	+0.1	— 9.9
4	—13.2	+ 3.6	—1.0	—11.5
5	— 4.3	—25.5	+1.3	— 6.3
6	— 1.7	—47.4	+2.8	— 6.1
7	— 5.6	—21.9	+1.0	— 7.2
8	+ 1.6	—18.2	+1.2	— 0.3
9	+ 7.3	—36.5	+2.7	+ 3.1
10	— 1.7	— 3.6	+0.2	— 1.9
11	+13.9	+ 7.3	+0.4	+13.3

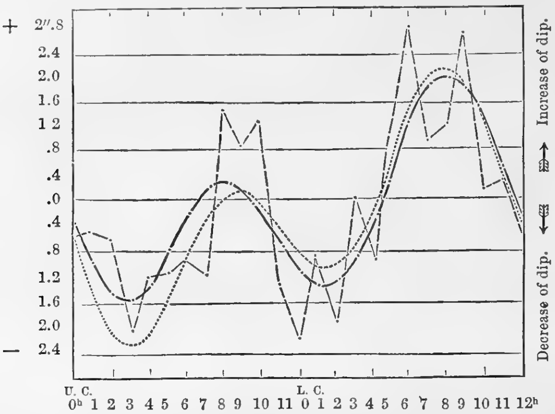
The numbers in column 2 are deduced from observations between 1841 and 1845, those in column 3 from observations between 1840 and 1845, the difference, however, is immaterial as far as it refers to the dip and total force, the lunar variations being nearly the same for a few adjacent years. The total number of observations employed in the combination is 41558.

The lunar-diurnal variation in the dip is well represented by the formula,

$$\theta_{\text{☾}} = -0''.06 + 0''.86 \sin(\theta + 156^\circ) + 1''.30 \sin(2\theta + 206^\circ)$$

the corresponding curve, as well as the observed values, are exhibited in the following diagram. The heavy smooth curve is the Philadelphia computed variation, the dotted curve the Toronto variation, inserted here for comparison. The correspondence between these curves is certainly remarkably close considering the minuteness of the lunar effect and the somewhat long process of deducing it.

(B.) Lunar-Diurnal Variation of the Inclination.

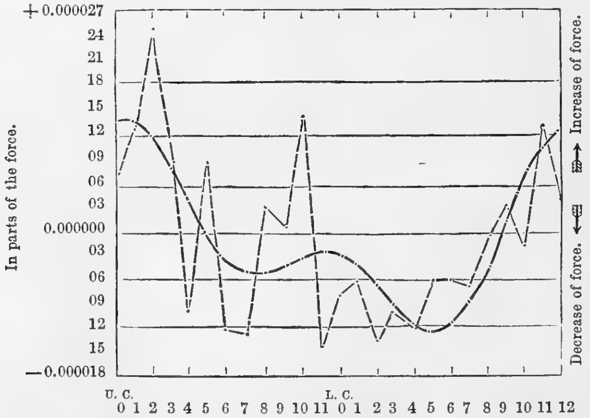


Maxima at 8^h and 20^h (principal), minima at 3^h (principal) and $13\frac{1}{2}^h$.
Total range 3″.6. Probable error of any single hourly representation ± 0″.7.
The lunar diurnal variation in the total force is represented by the equation:—

$$\Phi_{☾} = -\overset{M}{1.3} + \overset{M}{8.9} \sin(\theta + 63^\circ) + \overset{M}{6.3} \sin(2\theta + 84^\circ)$$

an expression not differing much from $V_{☾}$ owing to the large dip. The observed and computed values of $\frac{\Delta\Phi}{\Phi}$ are shown in the diagram, which nearly resembles that of the vertical force.

(C.) Lunar-Diurnal Variation of the Total Force.



Maxima at $\frac{1}{2}^h$ (principal) and 11^h; minima at $7\frac{1}{2}^h$ and 17^h (principal).
Total range 0.000026. Probable error of any single hourly representation ± 0.000006.

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DISCUSSION

OF THE

MAGNETIC AND METEOROLOGICAL OBSERVATIONS

MADE AT THE GIRARD COLLEGE OBSERVATORY, PHILADELPHIA,
IN 1840, 1841, 1842, 1843, 1844, AND 1845.

FOURTH SECTION,

COMPRISING PARTS X, XI, AND XII. DIP AND TOTAL FORCE.

ANALYSIS OF THE DISTURBANCES OF THE DIP AND TOTAL FORCE; DISCUSSION OF THE SOLAR
DIURNAL VARIATION AND ANNUAL INEQUALITY OF THE DIP AND TOTAL FORCE;
AND DISCUSSION OF THE ABSOLUTE DIP, WITH THE FINAL VALUES FOR
DECLINATION, DIP AND FORCE BETWEEN 1841 AND 1845.

BY

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[ACCEPTED FOR PUBLICATION, MAY, 1864.]

PART X.

ANALYSIS

OF THE

DISTURBANCES OF THE DIP AND TOTAL FORCE.

1 December, 1864.

ANALYSIS

OF THE

DISTURBANCES OF THE DIP AND TOTAL FORCE.

In the preceding discussion of the disturbances of the horizontal and vertical components of the magnetic force at the Girard College Observatory, the laws of their variations, as far as they have been recognizable from the series, were brought out and discussed, and this suffices, perhaps, in most cases, for any future application of theory, or for the purpose of testing hypotheses; but as it is also desirable for other comparisons to deduce the corresponding results for dip and total force from previous researches, it is proposed here to present the results of this combination numerically and in tabular form.

This combination is effected by the formulæ:—

$$\Delta\theta = \sin\theta\cos\theta\left(\frac{\Delta Y}{Y} - \frac{\Delta X}{X}\right) \text{ and } \frac{\Delta\phi}{\phi} = \sin^2\theta\frac{\Delta Y}{Y} + \cos^2\theta\frac{\Delta X}{X}$$

which expressions have already been used in the preceding part.

A strict treatment of the disturbances of either the dip or total force would require the formation of the difference of each observation of the vertical and horizontal force from its normal value (corresponding to the hour, month, and year), the conversion of these differences from units of scale value into parts of the respective force, and finally the numerical combination of the contemporaneous values of the two instruments by means of the above formulæ. To treat over 44,000 observations in this manner is impracticably laborious, and makes it desirable to substitute in its place another process less cumbrous, but, as regards results, equally effective. The method adopted avoids also the labor of forming normals, and especially that of separating the disturbances anew for each element. The method pursued in the discussion of the Toronto observations answers all purposes, and has also been adopted for the Philadelphia series; a more distinct idea, however, is here given for the limiting value beyond which disturbances are recognized. The method is as follows: Returning to the manuscript tables which contain the observations reduced to a uniform temperature and corrected for progressive change, as far as this was practicable, each observation marked there as a disturbance, that is, which differed as much or more than ± 30 scale divisions from the normal of the vertical force, and as much or more than ± 33 from the normal of the horizontal force, was transcribed and at once converted into its equivalent in parts of the force to which it respectively belonged. One scale division of the vertical force magnetometer equals 0.000033 parts, and of the horizontal force magnetometer 0.0000365 parts of the respective force. These disturbances of the two components were tabulated in chronological order, and when, for any entry, but one of the constituent parts appeared disturbed, the corresponding difference from the normal of the contemporaneous second part, whatever amount that might be, was likewise entered in an adjoining column. The corresponding values of $\Delta\theta$ and $\frac{\Delta\phi}{\phi}$ were then easily computed for each disturbance, whether it occurred in both components or in one only.

Trustworthy contemporaneous readings of the two magnetometers commence with February, 1841, and continue to the close of the series in June, 1845; there is, however, an interval of time between the readings of the instruments which we are obliged to disregard; it amounts to but 5 minutes, the bifilar magnetometer having been read so much later.

As there is not generally a contemporaneous disturbance in the vertical and horizontal force, the total number of disturbed values obtained by the process explained above and employed, is necessarily much greater than it was for either of the components; it becomes therefore necessary to fix upon some limit of recognition for a disturbed value of the dip, and also of the total force. This is best done by the adoption of that value which will separate an equal proportion of disturbed values from the total number, as was done in the components; for the vertical component one in every 10.5 observations, for the horizontal component one in every 19.3 observations was separated as a disturbed value between February 1, 1841, and June 30, 1845; on the average, therefore, one in every 15 observations should be separated in the dip and total force series. During the time mentioned the number of observations of vertical force was 22,092, and of horizontal force 22,150, from which we should accordingly derive nearly 1470 disturbances. Now the number of computed values of $\Delta\theta$ and of $\frac{\Delta\phi}{\phi}$ is 2362, hence, marking in each set the 1470 highest values, the limit of $\pm 1.'1$ is reached in the dip, and ± 0.00094 in the total force, which constitute the limiting values at and beyond which disturbances are recognized in each element. To render the series of disturbance results homogeneous, the disturbances at the odd hours after October, 1843, have been omitted. At Toronto the limit for the recognition of disturbances in the dip(1) was 1.'0, and in the total force 0.0004 parts of the force.

ANALYSIS OF THE DISTURBANCES OF THE INCLINATION.

The number of values of inclination differing $\pm 1.'1$ or more from their normal amount, and which constitute the disturbance values is 1446, these are variously combined in the following tables, and, when necessary, are separated into two classes, those which increase and those which decrease the inclination; to the former the sign + is prefixed, to the latter the sign —. The aggregate and mean amount of disturbances are expressed in minutes of arc. The columns containing the number of disturbances are headed with the letter n. When ratios are given, they

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[1] Vol. III, p. xliii.

exhibit the proportion of the amount of disturbances during any given sub-period to the average amount of disturbances during the whole period. In the first and three subsequent tables the values for the first five months of 1841 are omitted, as there are no adequate means of extending the series beyond four full years.

TABLE I.—AGGREGATE AMOUNT AND NUMBER OF DISTURBANCES OF THE INCLINATION IN EACH MONTH, DIVIDED INTO DISTURBANCES WHICH INCREASE AND WHICH DECREASE THE INCLINATION.

The values in brackets for January, February, and March, are interpolated, and are the average values of the corresponding months of the year preceding and the year following.

	1841 and 1842.				1842 and 1843.				1843 and 1844.				1844 and 1845.				Sums 1841 to 1845.				Ratio.	
	+	n	—	n	+	n	—	n	+	n	—	n	+	n	—	n	+	n	—	n	+	—
July . .	24.′5	16	15.′7	10	31.′5	17	17.′2	9	16.′9	10	4.′4	3	1.′1	1	12.′8	8	74.′0	44	50.′1	30	0.55	0.73
August .	34.5	16	14.0	9	13.6	8	33.5	22	20.8	13	0.0	0	42.4	29	3.9	3	111.3	66	51.4	34	0.83	0.75
Sept'ber .	104.7	40	14.4	10	20.7	9	114.8	64	8.4	4	7.2	6	25.4	14	10.9	6	159.2	67	147.3	86	1.19	2.15
October .	69.7	32	13.6	9	19.5	11	40.2	27	7.2	4	10.1	6	10.0	7	21.8	11	106.4	54	85.7	53	0.79	1.25
November	79.9	31	12.4	5	35.2	16	6.8	4	9.9	7	3.9	3	40.3	19	1.5	1	165.3	73	24.6	13	1.24	0.35
December	75.5	36	27.2	18	12.4	8	9.5	6	29.6	20	4.9	4	31.7	17	37.3	20	149.2	81	78.9	48	1.12	1.15
January .	72.3	33	40.5	24	(50.7)	(27)	(23.2)	(14)	29.1	21	5.9	4	23.7	10	7.7	5	175.8	91	77.3	47	1.31	1.12
February	101.6	45	40.3	26	(57.6)	(26)	(22.2)	(14)	13.7	8	4.2	3	5.8	3	0.0	0	178.7	82	66.7	43	1.34	0.97
March .	31.6	17	27.0	16	(37.5)	(20)	(18.6)	(12)	43.4	24	10.3	8	19.1	13	5.5	4	131.6	74	61.4	40	0.99	0.92
April . .	52.2	26	14 2	10	56.0	30	17.4	10	29.5	20	12.0	6	29.4	17	6.6	4	167.1	93	50.2	30	1.25	0.73
May . .	41.1	25	30.5	15	39.7	18	34.5	18	7.9	4	1.6	1	22.0	10	4.7	3	110.7	57	71.3	37	0.83	1.04
June . .	39.9	21	21.8	13	9.1	7	20.7	11	1.4	1	5.9	4	23.8	17	8.8	5	74.2	46	57.2	33	0.56	0.84

It would appear that during the colder season both sets of ratios present greater values; between September and February (inclusive) this ratio is, on the average, 1.16, and in the other months it is 0.84. Of the ratios decreasing the inclination the September and November values are somewhat anomalous, the first too high, the second too low.

The following table gives the annual inequality of the disturbances, irrespective of their sign.

TABLE II.—AGGREGATE AMOUNT AND NUMBER OF DISTURBANCES OF THE INCLINATION IN EACH MONTH.

The series comprises the four years between July, 1841, and July, 1845. The ratio is that of the sums.

	Sum.	n	Ratio.
July	124.′1	74	0.62
August	162.7	100	0.80
September	306.5	153	1.51
October	192.1	107	0.95
November	189.9	86	0.94
December	228.1	129	1.13
January	253.1	138	1.25
February	245.4	125	1.22
March	193.0	114	0.96
April	217.3	123	1.07
May	182.0	94	0.90
June	131.4	79	0.65

The ratio near the autumnal equinox is the greatest of all, that about the vernal equinox is a little below the average value; the least value occurs probably near the summer solstice.

TABLE III.—AGGREGATE AMOUNT AND NUMBER OF DISTURBANCES OF THE INCLINATION IN THE DIFFERENT YEARS OF OBSERVATION.

The ratios exhibit the variation due to the eleven year inequality.

Year.	Sum.	n	Ratio.
1841—1842	999.′1	503	1.65
1842—1843	742.1	408	1.22
1843—1844	288.2	184	0.47
1844—1845	396.2	227	0.66

The minimum amount of disturbances in the eleven year circle, therefore, occurred in the beginning of 1844.

TABLE IV.—AGGREGATE AMOUNT AND NUMBER OF DISTURBANCES IN EACH YEAR ARRANGED FOR DISTURBANCES INCREASING THE INCLINATION AND FOR THOSE DECREASING IT; TOGETHER WITH THE RATIOS OF THE SUMS.

	Sum.		Sum		Ratio.	
Year.	+	n	−	n	+	−
1841—1842	727.′5	338	271.′6	165	1.81	1.32
1842—1843	383.5	197	358.6	211	0.96	1.74
1843—1844	217.8	136	70.4	48	0.55	0.35
1844—1845	274.7	157	121.5	70	0.68	0.59

The minimum of the eleven year period is equally well marked in the disturbances increasing and in those decreasing the inclination. The sum of the positive values (1603.′5) is to the sum of the negative values (822.′1) as 1.95 to 1. At Toronto, between 1844 and 1848, this ratio was 5.6 to 1; the ratio, however, increased from 2.7 to 8.5 to 1 during this time.

In Tables V and VI, which exhibit the diurnal inequality of the disturbances, the whole series between February, 1841, and June, 1845, is employed. The sums, numbers, and ratios given do not in strictness apply to the even hours, but to an epoch 20 minutes later.

TABLE V.—AGGREGATE AMOUNT AND NUMBER OF DISTURBANCES OF THE INCLINATION, DISTRIBUTED OVER THE EVEN HOURS OF THE DAY, AND RATIO SHOWING THE DIURNAL INEQUALITY OF THE SUM.

Hour.	Sum.	n	Ratio.
0	244.8	143	1.11
2	183.2	110	0.83
4	184.1	111	0.84
6	170.8	98	0.78
8	154.8	94	0.70
10	213.6	116	0.99
Noon	250.7	141	1.14
14	260.9	131	1.19
16	232.4	130	1.06
18	245.0	126	1.11
20	253.6	121	1.16
22	238.0	125	1.09

The hourly disturbances of the inclination exhibit a regular progression; between 1 A. M. and 11 A. M. the numbers fall short of the mean hourly value, and during the remaining afternoon and night hours they exceed this average value. The minimum occurs near 8 A. M. and the maximum near 8 P. M. There is, however, an indication of a superimposed smaller progression which, owing to the short series of observations, is not distinctly brought out. At Toronto we have a double progression, and the above ratios approximate to it. At Philadelphia a secondary maximum probably occurs about noon and a secondary minimum about 4 P. M.

Table VI shows the ratios at the different hours for disturbances increasing and disturbances decreasing the inclination.

TABLE VI.—AGGREGATE AMOUNT AND NUMBER OF HOURLY DISTURBANCES OF THE INCLINATION FOR INCREASING AND DECREASING VALUES; AND MEAN EFFECT OF DISTURBANCES.

Hour.	Sum. +	n	Sum. —	n	Ratio of sums.		Excess of increasing disturbances.	Average diurnal effect of disturbances.
					+	—		
0	163.′9	94	80.′9	49	1.15	1.06	+83.′0	+0.′06
2	101.7	61	81.5	49	0.71	1.06	+20.2	+0.02
4	82.4	51	101.7	60	0.58	1.33	—19.3	—0.02
6	97.1	57	73.7	41	0.68	0.96	+23.4	+0.02
8	97.8	58	57.0	36	0.69	0.74	+40.8	+0.03
10	130.2	64	83.4	52	0.91	1.09	+46.8	+0.04
Noon . . .	139.3	75	111.4	66	0.98	1.45	+27.9	+0.02
14	193.2	90	67.7	41	1.35	0.89	+125.5	+0.10
16	148.5	79	83.9	51	1.04	1.09	+64.6	+0.05
18	178.7	86	66.3	40	1.25	0.87	+112.4	+0.09
20	198.3	87	55.3	34	1.39	0.72	+143.0	+0.11
22	181.5	91	56.5	34	1.27	0.74	+125.0	+0.10

The disturbances which increase the inclination show a very regular single progression (the value at 2 P. M. only being slightly anomalous); their minimum occurs at 4 A. M., and their maximum at 8 P. M. The disturbances decreasing the inclination are small in number at all hours, and show a tendency at double progression; principal maximum about noon, principal minimum about 8 P. M., secondary maximum about 4 A. M., and secondary minimum about 8 A. M. At Toronto the results appear different, but it is absolutely necessary for effective comparison to have results from contemporaneous series. As at Toronto, the disturbances increasing the inclination greatly preponderate over those decreasing it; the accumulated effect of this difference is shown in the column headed "Excess" (Table VI). At the hour 4 A. M. alone, we find the increasing disturbances inferior, at the hour 8 P. M. the difference has reached its maximum; at Toronto this maximum occurred an hour or two after midnight. The last column of Table VI exhibits the average diurnal effect of the disturbances (exceeding 1.′1 their normal value), the plus sign indicating a preponderance of increasing dip; the number of days is 1297.

The distribution of the disturbances according to their magnitude for an equal increase of 1′ is as follows:—

Between	Number of disturbances.
1.1 and 2.1	1096
2.1 " 3.1	247
3.1 " 4.1	65
4.1 " 5.1	27
5.1 " 6.1	5
6.1 " 7.1	3
7.1 " 8.1	3
beyond	none.

ANALYSIS OF THE DISTURBANCES OF THE TOTAL FORCE.

The number of values of total force differing 0.00094 parts of the force from its normal amount, and which constitute the disturbance values, is 1470, which have been combined in a manner similar to that of the disturbances of the dip; an increasing total force is indicated by a + sign, a decreasing one by a — sign. The aggregate amount and mean amount of disturbances are expressed in parts of the force, and the letter n indicates the number of disturbances. In the tables of the annual inequality the series commences with July, 1841, in those of the diurnal inequality it commences with February, 1841. The ratios given are those of the aggregate amount.

TABLE VII.—AGGREGATE AMOUNT AND NUMBER OF DISTURBANCES OF THE TOTAL FORCE IN EACH MONTH, DIVIDED INTO DISTURBANCES WHICH INCREASE AND WHICH DECREASE THE FORCE.

The values in brackets for January, February, and March are interpolated, and are the average values of the corresponding months of the year preceding and the year following.

	1841 and 1842.				1842 and 1843.				1843 and 1844.			
	+	n	—	n	+	n	—	n	+	n	—	n
July	.02944	25	.04552	32	.01115	8	.02518	15	.00000	0	.00377	3
August	.01239	10	.00438	4	.00758	5	.02658	24	.00830	8	.00200	2
September	.01759	15	.02807	19	.02395	16	.06228	42	.01355	10	.00734	7
October	.02658	20	.00697	6	.01148	10	.00410	4	.00663	5	.00585	5
November	.02357	17	.02413	20	.00781	6	.00960	9	.01563	13	.02485	21
December	.07598	47	.05026	35	.00715	7	.00898	7	.03267	28	.00645	6
January	.06321	38	.04939	36	(.04792)	(32)	(.03222)	(24)	.03264	27	.01506	13
February	.07043	50	.03481	28	(.04151)	(30)	(.01984)	(16)	.01259	10	.00486	4
March	.01895	15	.02730	19	(.02711)	(22)	(.02574)	(19)	.03527	29	.02419	19
April	.04122	28	.02820	19	.03523	24	.02084	18	.02181	19	.01940	14
May	.04586	27	.02443	16	.02697	17	.01736	14	.00977	6	.00000	0
June	.02777	21	.01191	11	.00561	3	.01038	7	.00342	3	.02193	20

	1844 and 1845.				Sums 1841 to 1845.				Ratios.	
	+	n	—	n	+	n	—	n	—	+
July	.00805	8	.01076	9	.04864	41	.08523	59	0.56	1.28
August	.04661	35	.01348	10	.07488	58	.04644	40	0.87	0.70
September	.00715	5	.00108	1	.06224	46	.09877	69	0.72	1.48
October	.00331	3	.00809	5	.04800	38	.02501	20	0.56	0.38
November	.00000	0	.00100	1	.04701	36	.05958	51	0.54	0.89
December	.01365	12	.00416	4	.12945	94	.06985	52	1.50	1.05
January	.00210	2	.00543	4	.14587	99	.10210	77	1.68	1.53
February	.00000	0	.00216	2	.12453	90	.06167	50	1.44	0.92
March	.02489	20	.01231	11	.10622	86	.08954	68	1.23	1.34
April	.00513	4	.00463	3	.10339	75	.07307	54	1.20	1.10
May	.02511	12	.00211	2	.10771	62	.04390	32	1.24	0.65
June	.00270	2	.00108	1	.03950	29	.04530	39	0.46	0.68

The ratios of the increasing disturbances of the force have a double progression, as have also those of the decreasing disturbances, though not so well marked. Increasing disturbances show a principal maximum in January, a principal minimum in June, and a secondary maximum and minimum in August and November, respectively; decreasing disturbances show a principal maximum in January, a principal minimum in October, and a secondary maximum and minimum in September and May, respectively. It appears, therefore, that upon the whole we observe the same laws as at Toronto, viz: the disturbances increasing the force and those decreasing the force follow the same progressive monthly change, and exhibit maximum values about the equinoxes, and minimum values about the solstices. This last remark also applies to the results of the following table in which the annual inequality of the disturbances is given irrespective of sign.

TABLE VIII.—AGGREGATE AMOUNT AND NUMBER OF DISTURBANCES OF THE TOTAL FORCE IN EACH MONTH AND RATIO OF SUMS.

	Sum.	n	Ratio.
July	.013387	100	0.87
August	0.12132	98	0.79
September	0.16101	115	1.05
October	0.07301	58	0.47
November	0.10659	87	0.70
December	0.19930	146	1.30
January	0.24797	176	1.62
February	0.18620	140	1.22
March	0.19576	154	1.28
April	0.17646	129	1.15
May	0.15161	94	0.99
June	0.08480	68	0.56

TABLE IX.—AGGREGATE AMOUNT AND NUMBER OF DISTURBANCES OF THE TOTAL FORCE IN THE DIFFERENT YEARS OF OBSERVATION.

The ratios of the sums exhibit part of the eleven year inequality.

Year.	Sum.	n	Ratio.
1841—1842	.78836	558	1.72
1842—1843	.51657	379	1.13
1843—1844	.32798	272	0.71
1844—1845	.20499	156	0.44

The minimum of the eleven year period, according to the above ratio, occurred probably in 1845.

Table X.—Aggregate amount and number of Disturbances in each Year (July to July) arranged for Disturbances Increasing and Disturbances Decreasing the Force, with Ratios of Sums.

	Sum.		Sum.		Ratio.	
Year.	+	n	−	n	+	−
1841—1842	.45299	313	.33537	245	1.75	1.67
1842—1843	.25347	180	.26310	199	0.98	1.32
1843—1844	.19228	158	.13570	114	0.74	0.68
1844—1845	.13870	103	.06629	53	0.53	0.33

The inequality of the eleven year period is equally well marked for disturbances increasing and for disturbances decreasing the total force.

The sum of the positive values is 1.03744, and of the negative values 0.80046; increasing disturbances are therefore preponderating in the ratio of 1.3 to 1. In the year 1842–1843, however, decreasing disturbances were in excess over increasing ones, and at Toronto between 1844 and 1848, the general effect of the larger disturbances of the force was to decrease the total magnetic force more than to increase it. The excess in the different years appears to be rather irregular.

The following tables exhibit the diurnal inequality of the disturbances, the whole series (beginning with February, 1841) is employed. The sums, numbers, and ratios given apply to an epoch 20 minutes later than indicated by the tables.

Table XI.—Aggregate amount and number of Disturbances of the Total Force, distributed over the even Hours of the Day, and Ratio showing the Diurnal Inequality of the Sum.

Hour.	Sum.	n	Ratio.
0	.19733	150	1.19
2	.20046	148	1.22
4	.20018	148	1.21
6	.17163	121	1.04
8	.13858	106	0.84
10	.13691	105	0.83
Noon	.15058	115	0.92
14	.19949	144	1.21
16	.14958	116	0.91
18	.13974	103	0.85
20	.13176	97	0.80
22	.16077	117	0.98

The hourly disturbances exhibit a regular double progression with a principal maximum at 2 A. M., and a principal minimum at 8 P. M., also a secondary maximum about 2 P. M., and a secondary minimum abut 10 A. M. At Toronto these hours were respectively 3 A. M., 11 A. M., and 5 P. M., 9 P. M., showing an exchange of the hours of the principal and secondary minimum; the disturbance at the hour of maximum is about eleven times greater than at the minimum hour, whereas this proportion is but one and a half to one at Philadelphia.

Table XII.—Aggregate amount and number of Hourly Disturbances of the Total Force for increasing and decreasing Values, Ratios, and Mean Effect of Disturbances.

Hour.	Sum. +	n	Sum. −	n	Ratio of sum.		Differences of sums.	Average diurnal effect.
					+	−		
0	.10570	83	.09163	67	1.22	1.18	+.01407	+.000011
2	.08589	68	.11457	80	0.99	1.47	−.02868	−.000022
4	.08264	66	.11754	82	0.95	1.51	−.03490	−.000027
6	.08449	57	.08714	64	0.97	1.12	−.00265	−.000002
8	.06261	48	.07597	58	0.72	0.97	−.01336	−.000010
10	.06364	46	.07327	59	0.73	0.94	−.00963	−.000008
Noon	.07094	51	.07964	64	0.82	1.02	−.00870	−.000007
14	.13083	86	.06866	58	1.50	0.88	+.06217	+.000049
16	.08664	66	.06294	50	1.00	0.81	+.02370	+.000018
18	.08880	64	.05094	39	1.02	0.66	+.03786	+.000029
20	.08223	60	.04953	37	0.95	0.64	+.03270	+.000025
22	.09791	71	.06286	46	1.13	0.80	+.03505	+.000027

The ratios of the increasing and decreasing disturbances appear to follow the same law, that is, the values at any hour appear to be complementary to one another, a high plus value corresponding to a low minus value; the phenomenon is, however, not so distinctly brought out as from the longer series at Toronto. The last two columns contain the difference of the sums at each hour, and the average effect of the larger disturbances of the total force. From 1 P. M. to 1 A. M. the larger disturbances augment the total force; from 1 A. M. to 1 P. M. they diminish it; greatest augmentation at 2 P. M., greatest diminution at 4 A. M. The greatest augmentation is nearly twice as great as the greatest diminution, whereas at Toronto the opposite effect was observed.

The distribution of the disturbances of the total force, according to their magnitude for an equal increase of .00090 parts of the force, is as follows:—

Between	Number of disturbances.
.00094 and .00184	1324
.00184 " .00274	122
.00274 " .00364	17
.00364 " .00454	4
.00454 " .00544	2
.00544 " .00634	0
.00634 " .00724	1
beyond	none

PART XI.

SOLAR DIURNAL VARIATION AND ANNUAL INEQUALITY OF THE INCLINATION AND TOTAL FORCE.

SOLAR-DIURNAL VARIATION OF THE DIP AND TOTAL FORCE.

To make the combination of the horizontal and vertical force components complete, there remains the discussion of the regular solar-diurnal variation and its annual inequality, of the resulting dip and total force.

Table III, of Part V, contains the solar-diurnal variation, expressed in parts of the force, of the horizontal component, freed from the larger disturbances; Table III, of Part VIII, contains similar information with regard to the vertical component. The numbers of these tables, however, cannot be combined directly, owing to the eleven year inequality which requires that the two sets of components should cover precisely the same interval of time. In the present case the table of the horizontal force extends from July, 1840, to July, 1845, a five year series; whereas the table of the vertical force extends over four years only; a new table of monthly normals of the horizontal component was therefore prepared, in which the first year's observations were omitted. This was done by the same method as had been followed in the preparation of the former annual values of Part V. The following table differs from that of Table I, of Part V, only in the number of observations employed, and extends from July, 1841, to July, 1845.

TABLE I.—RECAPITULATION OF THE HOURLY NORMALS OF THE HORIZONTAL FORCE (EXPRESSED IN SCALE DIVISIONS) FOR EACH MONTH OF THE YEAR, AND FOR SUMMER, WINTER, AND THE WHOLE YEAR, BETWEEN JULY, 1841, AND JULY, 1845.

1841–45	0^h	1	2	3	4	5	6	7	8	9	10	11^h	$+21\frac{1}{2}^m$
July . .	791	790	789	788	787	786	785	788	796	803	806	804	
August . .	813	813	813	812	811	809	808	815	825	835	837	830	
September .	829	827	830	829	826	824	821	830	842	850	853	852	
October . .	850	846	847	845	844	844	844	848	854	860	865	864	
November .	853	852	850	849	848	846	845	849	853	859	862	865	
December .	883	879	878	877	874	873	871	872	874	878	885	892	
January . .	905	902	902	901	899	899	899	898	900	908	914	918	
February . .	915	914	913	912	910	908	906	908	910	914	920	922	
March . .	919	917	915	915	915	913	912	915	920	927	931	936	
April . .	945	944	944	942	940	938	938	940	948	958	965	966	
May . .	947	946	944	942	942	940	938	944	954	961	960	956	
June . .	972	972	972	972	969	966	962	968	973	980	983	980	
Year . .	885.2	883.5	883.1	882.0	880.4	878.8	877.4	881.2	887.4	894.4	898.4	898.8	
Summer . .	882.8	882.0	882.0	880.8	879.2	877.2	875.3	880.8	889.7	897.8	900.7	898.0	
Winter . .	887.5	885.0	884.2	883.2	881.7	880.5	879.5	881.7	885.2	891.0	896.2	899.5	

The summer months comprise April to September, inclusive
The winter " " October to May, "
One scale division equals 0.0000365 parts of the force.
Increasing numbers denote decrease of force.

1841–1845	12^h (Noon)	13	14	15	16	17	18	19	20	21	22	23^h	$+21\frac{1}{2}^m$
July . .	797	788	782	780	779	783	788	791	793	793	793	793	
August . .	820	811	803	802	804	809	815	816	817	816	816	815	
September .	844	834	829	828	828	832	834	834	832	834	832	832	
October . .	866	860	856	854	854	854	854	854	855	853	853	852	
November .	861	858	853	852	851	853	851	851	852	852	853	853	
December .	894	889	885	880	878	878	879	880	882	884	884	883	
January . .	916	909	905	900	899	902	905	905	904	905	905	904	
February . .	925	920	915	912	915	915	916	919	921	917	915	915	
March . .	934	930	923	918	921	923	924	923	921	920	921	920	
April . .	960	957	947	944	943	944	948	948	949	950	947	947	
May . .	951	943	938	938	938	939	945	947	949	949	948	945	
June . .	974	969	962	961	961	965	970	971	971	972	973	973	
Year . .	895.2	889.0	883.2	880.7	880.9	883.1	885.7	886.5	887.2	887.1	886.7	886.0	
Summer . .	891.0	883.7	876.8	875.5	875.5	878.7	883.3	884.5	885.2	885.7	884.8	884.2	
Winter . .	899.3	894.0	889.5	886.0	886.3	887.5	888.2	888.7	889.2	888.5	888.5	887.8	

Subtracting each value from its respective monthly mean value and converting these differences into parts of the force, we obtain the numbers of Table II; a + sign indicates a greater force than the normal value, a — sign a smaller one. The first three decimals are placed at the head of the table.

TABLE II.—REGULAR SOLAR-DIURNAL VARIATION OF THE HORIZONTAL FORCE BETWEEN JULY, 1841, AND JULY, 1845. VALUES OF $\frac{\Delta X}{X}$.

0.000

	0^h	1	2	3	4	5	6	7	8	9	10	11^h	$+21\frac{1}{2}^m$
January . .	—025	+085	+085	+121	+194	+194	+194	+231	+158	—134	—353	—499	
February . .	—005	+032	+068	+105	+178	+251	+324	+251	+178	+032	—186	—259	
March . .	+087	+160	+233	+233	+233	+306	+342	+233	+050	—205	—351	—534	
April . .	+110	+146	+146	+219	+292	+365	+365	+292	000	—365	—620	—657	
May . .	—036	000	+073	+146	+146	+219	+292	+073	—292	—547	—511	—365	
June . .	—056	—056	—056	—056	+054	+163	+309	+090	—092	—348	—457	—348	
July . .	—017	+019	+056	+092	+129	+165	+202	+092	—200	—455	—565	—492	
August . .	+080	+080	+080	+117	+153	+226	+263	+007	—358	—723	—796	—540	
September .	+168	+241	+131	+168	+277	+350	+460	+131	—307	—599	—708	—672	
October . .	+116	+262	+225	+298	+335	+335	+335	+189	—030	—249	—435	—395	
November .	000	+035	+109	+145	+181	+254	+291	+145	000	—220	—329	—439	
December .	—091	+055	+091	+128	+237	+274	+347	+310	+237	+091	—164	—420	
Year . .	+027	+088	+103	+143	+201	+259	+310	+171	—055	—310	—456	—469	
Summer . .	+043	+072	+072	+116	+174	+247	+317	+116	—209	—505	—610	—512	
Winter . .	+014	+105	+134	+171	+226	+269	+305	+225	+098	—114	—303	—424	

0.000

	(Noon) 12^h	13	14	15	16	17	18	19	20	21	22	23^h	$+21\frac{1}{2}^m$
January . .	—427	—171	—025	+158	+194	+085	—025	—025	+011	—025	—025	+012	
February . .	—370	—186	—005	+105	—005	—005	—042	—151	—224	—078	—005	—005	
March . .	—461	—315	—059	+123	+014	—059	—096	—059	+014	+050	+014	+050	
April . .	—438	—328	+036	+146	+182	+146	000	000	—036	—073	+036	+036	
May . .	—182	+109	+292	+292	+292	+256	+036	—036	—109	—109	—073	+036	
June . .	—129	+054	+309	+346	+346	+200	+017	—019	—019	—056	—092	—092	
July . .	—236	+092	+311	+384	+421	+275	+092	—017	—090	—090	—090	—090	
August . .	—175	+153	+445	+482	+409	+226	+007	—029	—066	—029	—029	+007	
September .	—380	—015	+168	+204	+204	+058	—015	—015	+058	—015	+058	+058	
October . .	—468	—249	—103	—030	—030	—030	—030	—030	—067	+006	+006	+043	
November .	—293	—183	000	+035	+072	000	+072	+072	+035	+035	000	000	
December .	—493	—310	—164	+018	+091	+091	+055	+018	—055	—128	—128	—091	
Year . .	—338	—112	+100	+189	+183	+103	+006	—023	—046	—043	—028	—003	
Summer . .	—257	+011	+262	+309	+309	+192	+025	—019	—044	—063	—030	—008	
Winter . .	—416	—236	—059	+068	+057	+014	—012	—030	—048	—023	—023	+004	

To render the preceding table uniform with the similar one of the vertical component, the values at the odd hours will, hereafter, be dropped, their weight is less than one-half of that of the even hours; the small difference in the times (0.9^m) will be disregarded, and the values of the dip and total force, immediately deduced from the horizontal and vertical components, will refer to an epoch 21.1^m after the full hour.

For greater completeness, Table III, of Part VIII, is here inserted.

TABLE III.—REGULAR SOLAR-DIURNAL VARIATION OF THE VERTICAL FORCE BETWEEN JULY, 1841, AND JULY, 1845. VALUES OF $\frac{\Delta Y}{Y}$.

0.000

	0^h	2	4	6	8	10	Noon	14	16	18	20	22^h	$+20.6^m$
January. .	—059	+238	+040	—026	—026	+172	+172	+304	—092	—323	—224	—158	
February .	—198	+033	—132	—165	+099	+231	+264	+396	+198	—264	—330	—132	
March . .	—178	+086	—046	—112	+086	+119	+251	+317	+020	—178	—145	—211	
April . .	—353	—155	—122	—023	+175	+274	+274	+340	+241	—023	—320	—320	
May . .	—412	—346	—214	+049	+247	+280	+346	+445	+313	+016	—313	—412	
June . .	—528	—297	—198	—033	+198	+396	+594	+462	+363	—066	—429	—462	
July . .	—571	—406	—241	+056	+221	+419	+584	+551	+386	—043	—406	—538	
August . .	—485	—386	—287	—089	+109	+406	+736	+571	+340	—023	—386	—485	
September .	—469	—304	—271	—205	+092	+323	+521	+521	+356	+026	—271	—337	
October . .	—099	+066	000	—099	+231	+198	+198	+198	—033	—198	—264	—198	
November .	—043	—043	—142	—109	+086	+122	+254	+221	—010	—076	—109	—109	
December .	—059	+139	+040	—059	+040	+139	+205	+205	—092	—290	—191	—125	
Year . .	—287	—115	—131	—068	+129	+257	+366	+377	+165	—121	—282	—290	
Summer. .	—469	—317	—221	—040	+175	+350	+508	+482	+333	—020	—353	—426	
Winter . .	—106	+086	—040	—096	+082	+162	+224	+274	000	—221	—211	—155	

Solar-Diurnal Variation of the Inclination.—The combination of the component values of $\frac{\Delta X}{X}$ and $\frac{\Delta Y}{Y}$ to form the corresponding values of the dip is effected by the formula

$$\Delta\theta = \sin\theta\cos\theta\left(\frac{\Delta Y}{Y} - \frac{\Delta X}{X}\right)$$

$\Delta\theta$ will be expressed in minutes. $\theta = 71° 59'$. A + sign indicates an augmentation of the north dip; a — sign the converse.

TABLE IV.—REGULAR SOLAR-DIURNAL VARIATION OF THE DIP BETWEEN JULY, 1841, AND JULY, 1845. VALUES OF $\Delta\theta$.

	0h	2	4	6	8	10	Noon	14	16	18	20	22h	+21.1m
Jan'y	—0.′03	+0.′15	—0.′16	—0.′22	—0.′19	+0.′53	+0.′61	+0.′33	—0.′30	—0.′31	—0.′24	—0.′13	
Feb'y	—0.20	—0.04	—0.32	—0.50	—0.08	+0.42	+0.63	+0.40	+0.20	—0.22	—0.11	—0.13	
March	—0.27	—0.15	—0.28	—0.46	+0.04	+0.48	+0.72	+0.38	+0.01	—0.08	—0.16	—0.23	
April	—0.47	—0.30	—0.41	—0.39	+0.18	+0.91	+0.73	+0.31	+0.06	—0.02	—0.28	—0.36	
May	—0.38	—0.43	—0.37	—0.25	+0.54	+0.80	+0.53	+0.15	+0.02	—0.02	—0.20	—0.34	
June	—0.47	—0.24	—0.25	—0.34	+0.30	+0.87	+0.75	+0.16	+0.02	—0.08	—0.40	—0.37	
July	—0.56	—0.46	—0.37	—0.15	+0.43	+1.00	+0.83	+0.24	—0.04	—0.14	—0.32	—0.45	
August	—0.57	—0.47	—0.44	—0.35	+0.47	+1.22	+0.92	+0.13	—0.07	—0.03	—0.32	—0.46	
Sept.	—0.63	—0.43	—0.54	—0.66	+0.41	+1.05	+0.92	+0.36	+0.15	+0.04	—0.33	—0.39	
Oct.	—0.23	—0.17	—0.35	—0.45	+0.25	+0.64	+0.67	+0.30	—0.02	—0.18	—0.21	—0.22	
Nov.	—0.04	—0.15	—0.32	—0.40	+0.09	+0.47	+0.56	+0.22	—0.08	—0.15	—0.14	—0.11	
Dec..	+0.03	+0.05	—0.20	—0.41	—0.20	+0.30	+0.71	+0.37	—0.18	—0.35	—0.14	—0.00	
Year	—0.32	—0.22	—0.33	—0.38	+0.19	+0.72	+0.71	+0.28	—0.02	—0.13	—0.24	—0.27	
Sum'r	—0.51	—0.39	—0.40	—0.36	+0.39	+0.98	+0.78	+0.22	+0.02	—0.04	—0.31	—0.40	
Winter	—0.12	—0.05	—0.27	—0.41	—0.01	+0.47	+0.65	+0.33	—0.06	—0.22	—0.17	—0.14	

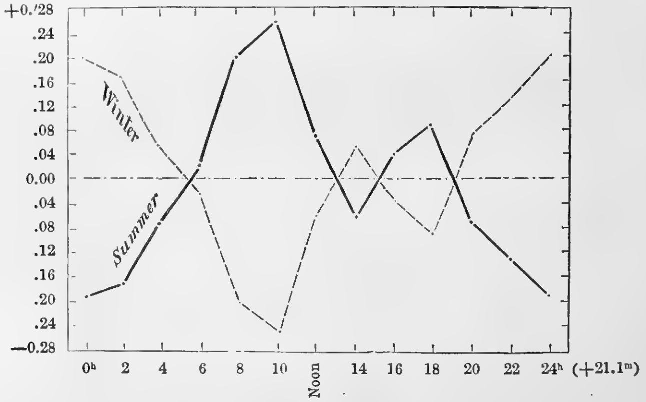
Annual Inequality in the Diurnal Variation of the Dip.—The comparison of the above diurnal variations for summer and winter, with that of the whole year, is given in the following Table.

TABLE V.

	0h	2	4	6	8	10	Noon	14	16	18	20	22h	+21.1m
Summer	—0.′19	—0.′17	—0.′07	+0.′02	+0.′20	+0.′26	+0.′07	—0.′06	+0.′04	+0.′09	—0.′07	—0.′13	
Winter	+0.20	+0.17	+0.06	—0.03	—0.20	—0.25	—0.06	+0.05	—0.04	—0.09	+0.07	+0.13	

The tabular quantities are exhibited in diagram A.

(A). SEMI-ANNUAL INEQUALITY IN THE DIURNAL VARIATION OF THE INCLINATION.



The diagram shows the hours of no semi-annual change as follows: $5\frac{1}{2}$ A. M.; 1 P. M.; 3 P. M., and 7 P. M.; greatest change at 10 A. M., secondary at 6 P. M., with a range of 0.′51 and 0.′18, respectively.

The turning epochs are found by the variation at the hour 10 A. M., when the monthly differences from the annual mean are as follows:—

January	—0.′19	July	+0.′28
February	—0.30	August	+0.50
March	—0.24	September . . .	+0.33
April	+0.19	October	—0.08
May	+0.08	November . . .	—0.25
June	+0.15	December . . .	—0.42

These values are represented by the formula

$$\Delta_a = 0.'35 \sin(\theta + 253^\circ 38') + 0.'10 \sin(2\theta + 328^\circ 39')$$

the angle θ counting from January 1st. This formula gives a change of sign for the middle of April and the middle of October, or about 25 days after the equinoxes.

ANALYSIS OF THE SOLAR-DIURNAL VARIATION OF THE DIP.

In the following formulæ expressing the solar-diurnal variation of the dip for each month, summer, winter, and year, the angle θ counts from midnight at the rate of 15° an hour; a positive sign indicates increase of north dip, a negative sign the reverse. The expressions are derived directly from Table IV.

For January $\Delta_i = 0.'24 \sin(\theta + 284^\circ 19') + 0.'33 \sin(2\theta + 78^\circ 15') + 0.'14 \sin(3\theta + 282^\circ)$
For February $\Delta_i = 0.'34 \sin(\theta + 246^\circ 28') + 0.'30 \sin(2\theta + 75^\circ 40') + 0.'08 \sin(3\theta + 308^\circ)$
For March $\Delta_i = 0.'40 \sin(\theta + 251^\circ 24') + 0.'24 \sin(2\theta + 85^\circ 27') + 0.'12 \sin(3\theta + 303^\circ)$
For April $\Delta_i = 0.'55 \sin(\theta + 263^\circ 10') + 0.'23 \sin(2\theta + 109^\circ 36') + 0.'18 \sin(3\theta + 330^\circ)$
For May $\Delta_i = 0.'50 \sin(\theta + 271^\circ 33') + 0.'22 \sin(2\theta + 146^\circ 40') + 0.'14 \sin(3\theta + 0^\circ)$
For June $\Delta_i = 0.'53 \sin(\theta + 274^\circ 37') + 0.'21 \sin(2\theta + 109^\circ 03') + 0.'19 \sin(3\theta + 331^\circ)$
For July $\Delta_i = 0.'64 \sin(\theta + 275^\circ 34') + 0.'24 \sin(2\theta + 131^\circ 08') + 0.'14 \sin(3\theta + 322^\circ)$
For August $\Lambda_i = 0.'68 \sin(\theta + 272^\circ 55') + 0.'32 \sin(2\theta + 132^\circ 56') + 0.'24 \sin(3\theta + 331^\circ)$
For September $\Delta_i = 0.'70 \sin(\theta + 260^\circ 14') + 0.'27 \sin(2\theta + 116^\circ 49') + 0.'23 \sin(3\theta + 349^\circ)$
For October $\Delta_i = 0.'41 \sin(\theta + 256^\circ 31') + 0.'27 \sin(2\theta + 101^\circ 19') + 0.'11 \sin(3\theta + 335^\circ)$
For November $\Delta_i = 0.'28 \sin(\theta + 259^\circ 21') + 0.'27 \sin(2\theta + 99^\circ 30') + 0.'08 \sin(3\theta + 328^\circ)$
For December $\Delta_i = 0.'20 \sin(\theta + 258^\circ 09') + 0.'37 \sin(2\theta + 77^\circ 45') + 0.'12 \sin(3\theta + 258^\circ)$

We have also:—

For Summer $\Delta_i = 0.'60 \sin(\theta + 269^\circ 37') + 0.'25 \sin(2\theta + 125^\circ 02') + 0.'18 \sin(3\theta + 335^\circ)$
For Winter $\Delta_i = 0.'30 \sin(\theta + 260^\circ 57') + 0.'29 \sin(2\theta + 85^\circ 12') + 0.'10 \sin(3\theta + 300^\circ)$
For Year $\Delta_i = 0.'45 \sin(\theta + 266^\circ 47') + 0.'25 \sin(2\theta + 103^\circ 19') + 0.'13 \sin(3\theta + 322^\circ)$

Summer is comprised of the months from April to September; winter of the months from October to March.

The following comparison of the observed and computed values for August shows about average differences; in general the summer values are a little better represented than the winter values.

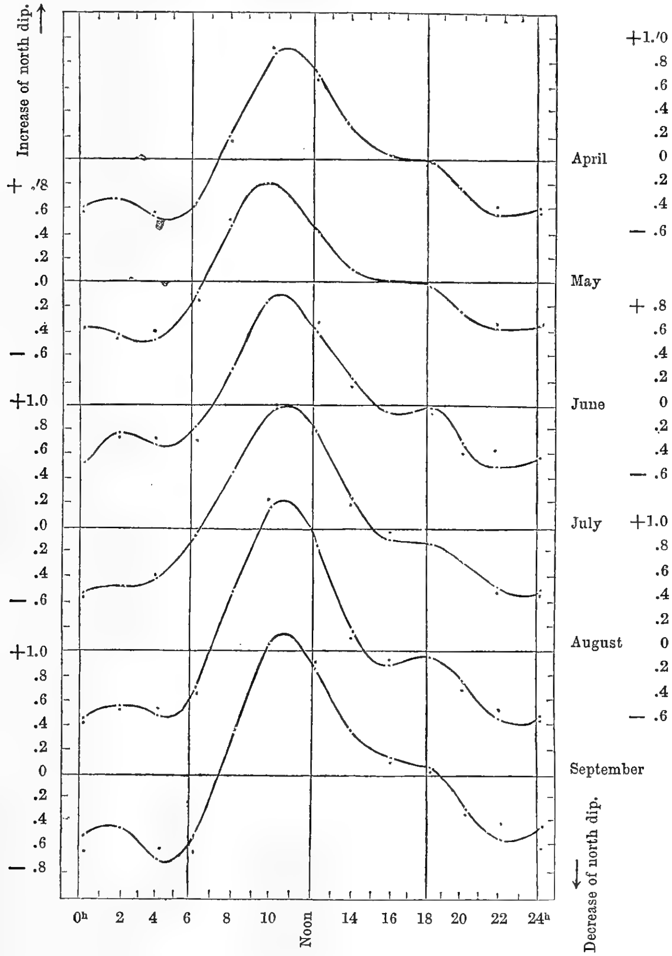
Comparison for August.

Time.	Observed.	Computed.	O—C.
0^h 21.1^m	—′.57	—′.53	—′.04
2 "	— .47	— .43	—.04
4 "	— .44	— .52	+.08
6 "	— .35	— .33	—.02
8 "	+ .47	+ .50	—.03
10 "	+1.22	+1.18	+.04
12 "	+ .92	+ .92	.00
14 "	+ .13	+ .18	—.05
16 "	— .07	— .12	+.05
18 "	— .03	— .05	+.02
20 "	— .32	— .24	—.08
22 "	— .46	— .55	+.09

Diagram (B) exhibits the observed and computed diurnal variation for the summer months, and diagram (C) for the winter months.

(B). SOLAR-DIURNAL VARIATION OF THE MAGNETIC DIP APRIL TO SEPTEMBER, 1841—1845.

(Expressed in minutes.)



Philadelphia mean time.

(C). Solar-Diurnal Variation of the Magnetic Dip October to March, 1841—1845.

(Expressed in minutes.)

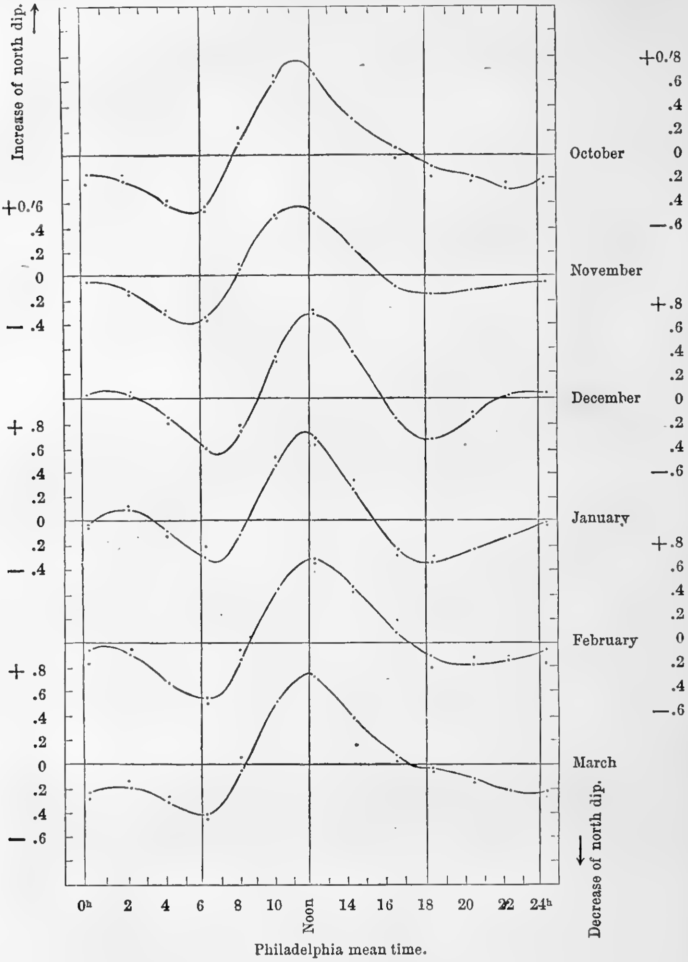
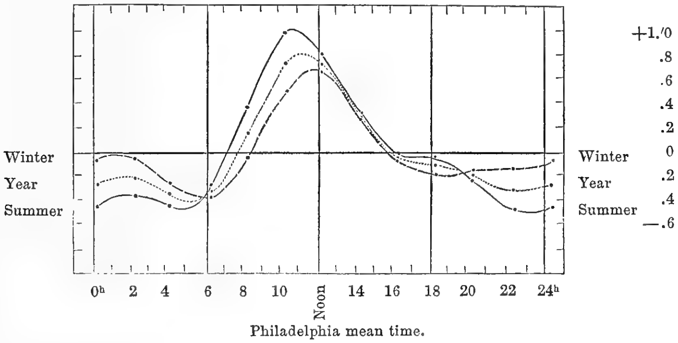


Diagram (D) exhibits the diurnal variation of the dip for summer, winter, and the whole year.

(D). SOLAR-DIURNAL VARIATION OF THE MAGNETIC DIP BETWEEN 1841 AND 1845.



The general character of the above three curves is the same; the annual curve has its greatest value about 11 A. M., and its least value about 5 A. M., with a range of about 1.′2; in summer the epochs occur a little earlier, with a range of about 1.′5; in winter the epochs are a little later, and the range is contracted to about 1.′0. There is also a secondary maximum between 1 and 2 A. M., with a less regular secondary minimum occurring at some hour in the afternoon or early in the night; in summer, however, these minima appear interchanged.

The Toronto curves are similar to those above, the shifting of the epochs is the same as at Philadelphia; the morning minimum is less prominent, and the afternoon minimum constitutes the principal minimum during summer, and also, on the average, during the year. The total annual range is almost exactly the same at the two places, and the times of the principal maxima also nearly coincide.

The following table contains the computed times of the principal maximum and of the morning minimum, also the elapsed time, together with the amount and range for each month and season; also the times and amount and range of the afternoon or early night minimum, taken from the preceding diagrams.

TABLE VI.

1841 to 1845.	Principal maximum at	Amount in minutes.	A. M. minimum at	Amount in minutes.	Elapsed time between max. and min.	A M. range.	Afternoon minimum about	Early night minimum about	Range of afternoon minimum & principal maximum
January	11^h 59^m	+0.'69	6^h 39^m	—0.'32	5^h 20^m	1.'01	6^h	—^{h}	1.'0
February	12 15	+0.67	6 04	—0.48	6 11	1.15	8	—	0.9
March	11 57	+0.72	5 54	—0.43	6 03	1.15	—	11	—
April	11 11	+0.92	5 11	—0.48	6 00	1.40	—	10	—
May	10 24	+0.81	4 07	—0.46	6 17	1.27	—	11	—
June	11 01	+0.91	5 16	—0.36	5 45	1.27	5	10	1.0
July	10 57	+1.00	3[1] 15	—0.43	7 42	1.43	5	11	1.1
August	10 49	+1.21	4 45	—0.53	6 04	1.74	4	11	1.3
September	10 56	+1.10	4 57	—0.69	5 59	1.79	—	10	—
October	11 25	+0.73	5 17	—0.49	6 08	1.22	—	10	—
November	11 29	+0.60	5 28	—0.40	6 01	1.00	6	—	0.7
December	12 24	+0.69	6 45	—0.41	5 39	1.10	6	—	1.0
Summer	10 55	+1.00	4 45	—0.48	6 10	1.48			
Winter	11 55	+0.67	6 00	—0.39	5 55	1.06			
Year	11 22	+0.81	5 18	—0.40	6 04	1.21			

The diurnal range is greater about the time of the equinoxes than at any other time, and in general less in winter and greater in summer. The afternoon minimum disappears about the time of the equinoxes, and is best marked about the solstices; the early night minimum only disappears about the time of the winter solstice.

TABLE VII.—PRINCIPAL EPOCHS OF NORMAL DIP.

The morning epoch is computed to the nearest minute or two, the afternoon epoch is taken from the diagrams.

1841—1845.	A. M.	P. M.
January	8^h 38^m	3¼^h
February	8 49	5
March	8 35	5
April	7 46	5¾
May	6 52	5½
June	7 11	3¾
July	6 55	3¼
August	7 16	3
September	7 37	6¾
October	8 03	5
November	8 10	3½
December	9 14	3½
Summer	7 22	4
Winter	8 33	3½
Year	7 50	3¼

Solar-Diurnal Variation of the Total Force.—The combination of the component values of $\frac{\Delta X}{X}$ and $\frac{\Delta Y}{Y}$ to form the corresponding values of the total force is effected by the formula

$$\frac{\Delta\phi}{\phi} = sin\ ^2\theta \frac{\Delta Y}{Y} + cos\ ^2\theta \frac{\Delta X}{X}$$

the result being expressed in parts of the force. A + sign indicates an augmentation of the force, a — sign a diminution.

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[1] About 3¼ A. M.; minimum not distinctly marked.

TABLE VIII.—REGULAR SOLAR-DIURNAL VARIATION OF THE TOTAL FORCE BETWEEN JULY, 1841, AND JULY, 1845.

Values of $\frac{\Delta\phi}{\phi}$ to six places of decimals, the first three are placed outside the table.

0.000

	0h	2	4	6	8	10	Noon	14	16	18	20	22h	+21.1m
January . .	—056	+224	+055	—004	—007	+122	+115	+273	—064	—294	—202	—144	
February. .	—178	+038	—100	—115	+108	+190	+193	+358	+178	—241	—319	—119	
March. . .	—152	+099	—019	—068	+082	+072	+183	+280	+019	—169	—130	—189	
April . . .	—308	—126	—081	+015	+158	+188	+205	+311	+236	—021	—292	—286	
May . . .	—375	—305	—179	+073	+194	+203	+294	+431	+312	+017	—294	—379	
June . . .	—483	—274	—175	—001	+169	+312	+523	+447	+362	—058	—391	—428	
July . . .	—519	—363	—206	+069	+182	+323	+504	+527	+387	—031	—377	—496	
August . .	—433	—343	—246	—056	+062	+289	+646	+557	+345	—022	—357	—444	
September .	—408	—263	—218	—142	+054	+226	+436	+488	+343	+022	—240	—299	
October . .	—077	+082	+033	—056	+208	+138	+135	+169	—032	—180	—244	—177	
November .	—043	—033	—114	—074	+075	+075	+197	+196	—006	—065	—099	—102	
December .	—059	+137	+062	—017	+062	+112	+142	+173	—071	—254	—174	—122	
Year . . .	—257	—094	—099	—031	+112	+187	+298	+351	+167	—108	—260	—265	
Summer . .	—421	—279	—184	—007	+137	+257	+435	+460	+331	—016	—325	—389	
Winter. . .	—094	+091	—014	—056	+088	+118	+161	+241	+004	—200	—195	—142	

Annual Inequality in the Diurnal Variation of the Total Force.—The comparison of the above diurnal variations for summer and winter, with that of the whole year, is given in the following table:—

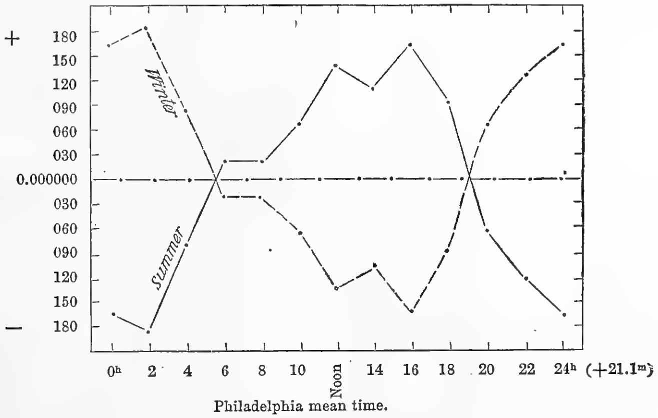
TABLE IX.

0.000

	0h	2	4	6	8	10	Noon	14	16	18	20	22h	+21.1m
Summer . .	—164	—185	—085	+024	+025	+070	+137	+109	+164	+092	—065	—124	
Winter . .	+163	+185	+085	—025	—024	—069	—137	—110	—163	—092	+065	+123	

These tabular quantities are exhibited in diagram E, which closely resembles diagram B, Part VIII, of the Vertical Force.

(E). SEMI-ANNUAL INEQUALITY IN THE DIURNAL VARIATION OF THE TOTAL FORCE.



The hours of no semi-annual change are 6 A. M. and 7 P. M.; the greatest changes take place about 2 A. M. and 4 P. M., with a range of .000370 and .000328 parts of the force respectively.

The turning epochs are found from the variations at the hours 6 A. M. and 7 P. M. The following numbers are the differences from the respective annual means. For 20^h the sign has been changed.

	6 A. M.	Mean 18 and 20.	Mean 6 A. M. 7 P. M.
January	+027	—122	—048
February	—084	—037	—060
March	—037	—095	—066
April	+046	+060	+053
May	+104	+080	+092
June	+030	+090	+060
July	+100	+097	+098
August	—025	+091	+033
September	—111	+055	—028
October	—025	—044	—034
November	—043	—059	—051
December	+014	—116	—051

All expressed in units of the sixth place of decimals.

The values in the last column are represented by the formula:—

$$\Delta_a = 0.000075 \ sin \ (\theta + 280^\circ) + 0.000025 \ sin \ (2\theta + 131^\circ)$$

θ counting from January 1st. The change of sign occurs about April 4th and about September 12th, on the average, therefore, the change takes place about three days after the equinoxes.

ANALYSIS OF THE SOLAR-DIURNAL VARIATION OF THE TOTAL FORCE.

In the following expressions of the solar-diurnal variation of the total force, θ is counted from midnight at the rate of 15° an hour; a positive sign indicates increase of total force, a negative sign the reverse. The coefficients are expressed in parts of the force. The formulæ are deduced directly from Table VIII.

For January $\Delta_f = 0.000139 \ sin \ (\theta + 318^\circ \ 14') + 0.000157 \ sin \ (2\theta + 37^\circ \ 57') + 0.000020 \ sin \ (3\theta + 217^\circ)$

For February $\Delta_f = 0.000215 \ sin \ (\theta + 276^\circ \ 00') + 0.000143 \ sin \ (2\theta + 41^\circ \ 01') + 0.000060 \ sin \ (3\theta + 96^\circ)$

For March $\Delta_f = 0.000148 \ sin \ (\theta + 284^\circ \ 00') + 0.000106 \ sin \ (2\theta + 31^\circ \ 27') + 0.000014 \ sin \ (3\theta + 242^\circ)$

For April $\Delta_f = 0.000283 \ sin \ (\theta + 270^\circ \ 27') + 0.000084 \ sin \ (2\theta + 342^\circ \ 03') + 0.000042 \ sin \ (3\theta + 74^\circ)$

For May $\Delta_f = 0.000383 \ sin \ (\theta + 264^\circ \ 08') + 0.000084 \ sin \ (2\theta + 325^\circ \ 13') + 0.000062 \ sin \ (3\theta + 108^\circ)$

For June $\Delta_f = 0.000470 \ sin \ (\theta + 266^\circ \ 26') + 0.000108 \ sin \ (2\theta + 2^\circ \ 57') + 0.000016 \ sin \ (3\theta + 96^\circ)$

For July $\Delta_f = 0.000513 \ sin \ (\theta + 265^\circ \ 24') + 0.000103 \ sin \ (2\theta + 344^\circ \ 53') + 0.000036 \ sin \ (3\theta + 126^\circ)$

For August $\Delta_f = 0.000500 \ sin \ (\theta + 259^\circ \ 41') + 0.000109 \ sin \ (2\theta + 29^\circ \ 29') + 0.000025 \ sin \ (3\theta + 193^\circ)$

For September $\Delta_f = 0.000405 \ sin \ (\theta + 252^\circ \ 37') + 0.000097 \ sin \ (2\theta + 15^\circ \ 05') + 0.000010 \ sin \ (3\theta + 163^\circ)$

For October $\Delta_f = 0.000170 \ sin \ (\theta + 307^\circ \ 00') + 0.000084 \ sin \ (2\theta + 45^\circ \ 35') + 0.000033 \ sin \ (3\theta + 44^\circ)$

For November $\Delta_f = 0.000122 \ sin \ (\theta + 266^\circ \ 37') + 0.000074 \ sin \ (2\theta + 68^\circ \ 28') + 0.000010 \ sin \ (3\theta + 119^\circ)$

For December $\Delta_f = 0.000136 \ sin \ (\theta + 317^\circ \ 52') + 0.000112 \ sin \ (2\theta + 46^\circ \ 38') + 0.000017 \ sin \ (3\theta + 234^\circ)$

The months from April to September are counted as summer months; those from October to March as winter months.

For Summer $\Delta_f = 0.000426 \ sin \ (\theta + 262^\circ \ 51') + 0.000095 \ sin \ (2\theta + 358^\circ \ 00') + 0.000026 \ sin \ (3\theta + 114^\circ)$

For Winter $\Delta_f = 0.000146 \ sin \ (\theta + 292^\circ \ 00') + 0.000110 \ sin \ (2\theta + 43^\circ \ 20') + 0.000007 \ sin \ (3\theta + 119^\circ)$

For Year $\Delta_f = 0.000277 \ sin \ (\theta + 270^\circ \ 45') + 0.000095 \ sin \ (2\theta + 22^\circ \ 29') + 0.000018 \ sin \ (3\theta + 115^\circ)$

The following comparison of the observed and computed values for September shows about average differences; in general the summer values are better represented or less irregular than the winter values.

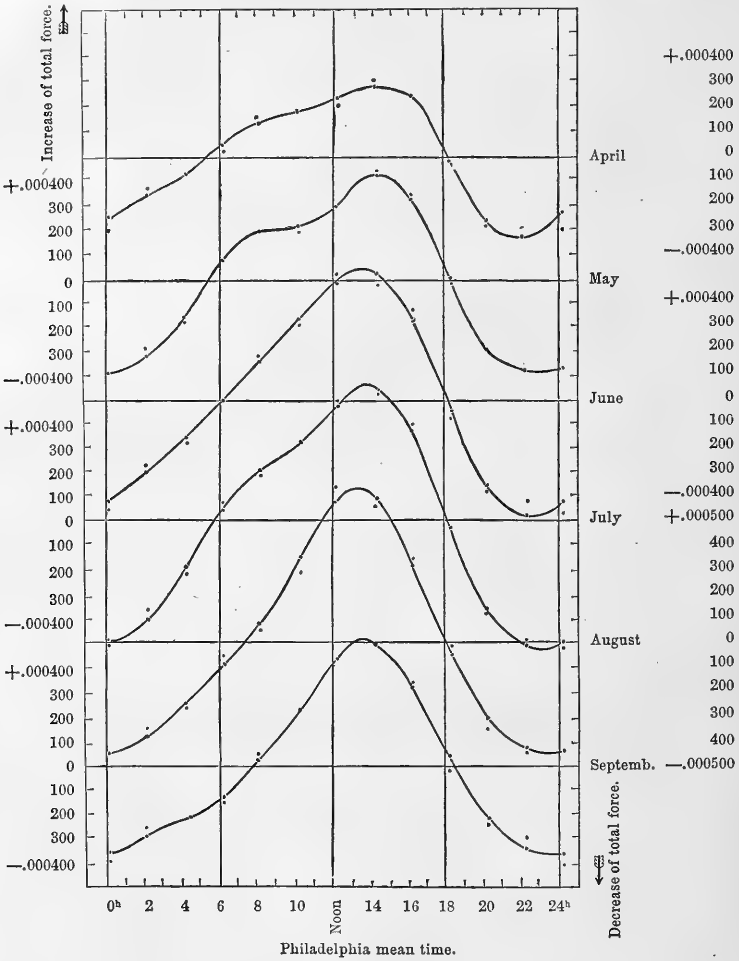
COMPARISON FOR SEPTEMBER.

Time.	Observed.	Computed.	O—C.
$0^h\ 21.1^m$	—.000408	—.000355	—.000053
2 "	—.000263	—.000298	+.000035
4 "	—.000218	—.000217	—.000001
6 "	—.000142	—.000127	—.000015
8 "	+.000054	+.000029	+.000025
10 "	+.000226	+.000236	—.000010
12 "	+.000436	+.000439	—.000003
14 "	+.000488	+.000492	—.000004
16 "	+.000343	+.000325	+.000018
18 "	+.000022	+.000033	—.000011
20 "	—.000240	—.000223	—.000017
22 "	—.000299	—.000344	+.000045

Diagram (F) exhibits the observed and computed diurnal variation for the summer months, and diagram (G) for the winter months.

(F). Solar-Diurnal Variation of the Magnetic Total Force April to September, 1841—1845.

(Expressed in parts of the force.)



(G). SOLAR-DIURNAL VARIATION OF THE MAGNETIC TOTAL FORCE OCTOBER TO MARCH, 1841—1845.

(Expressed in parts of the force.)

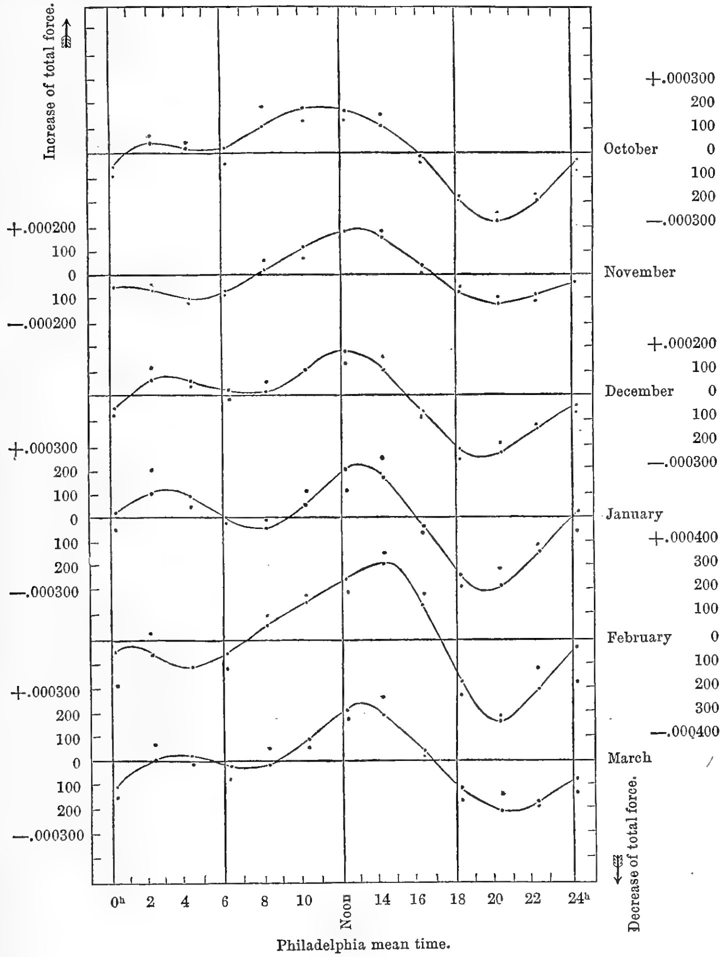
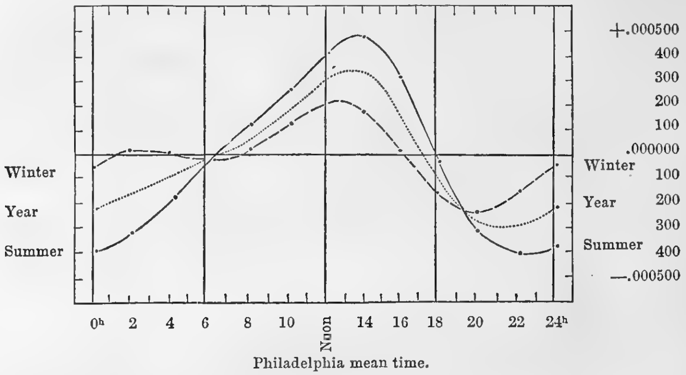


Diagram (H) exhibits the diurnal variation of the total force for summer, winter, and the whole year.

(H). Solar-Diurnal Variation of the Total Force between 1841 and 1845.



The diurnal curve is single crested in summer, and on the average during the year, but in winter it assumes a double crested form, having a secondary maximum between 2 and 3 A. M., and a secondary minimum about 6 A. M. The principal maximum in summer occurs about 2 P. M., and in winter about one and a half hours earlier; the principal minimum in summer occurs about 10 P. M., and in winter about two hours earlier. The summer range is about 0.0009, and the winter range about 0.0004 parts of the force.

The following table contains the computed times of the principal maximum and minimum, together with the elapsed time, amount and range of variation in force for each month and season, also the time and amount of range of early morning secondary wave as taken from the diagrams.

Table X.—Total Force.

1841—1845.	Principal maximum.	Amount 0.000	Principal minimum.	Amount 0.000	Elapsed time.	A. M. & P. M. range 0.00	A. M. secondary maximum.	A. M. secondary minimum.	Secondary range .000
January	13h 02m	+225	19h 38m	—283	6h 36m	0508	3h	7½h	15
February	14 00	+320	20 19	—331	6 19	0651	1	4	07
March	13 07	+237	20 45	—204	7 38	0441	4	7	04
April	14 46	+299	21 54	—342	7 08	0641	—	—	—
May	14 46	+422	22 57	—404	8 11	0826	—	—	—
June	13 41	+521	22 32	—486	8 51	1007	—	—	—
July	14 04	+560	23 05	—522	9 01	1082	—	—	—
August	13 23	+618	23 42	—447	10 19	1065	—	—	—
September	13 54	+498	23 33	—360	9 39	0858	—	—	—
October	11 00	+190	20 30	—266	9 30	0456	2½	5	04
November	12 50	+199	20 02	—118	7 12	0317	0½	4½	04
December	12 33	+193	19 29	—231	6 56	0424	8	7	05
Summer	14 02	+485	22 38	—421	8 36	0906	—	—	—
Winter	12 58	+220	20 11	—229	7 13	0449	2½	6	04
Year	13 36	+344	21 28	—296	7 52	0640	—	—	—

The amount and range are expressed in parts of the force. The time of the principal maximum and minimum is computed to the nearest one or two minutes. The diurnal range is greatest during summer, and least during winter. The small secondary inflexion obtains only during the winter months; its range is only about the seventieth part of the larger annual range.

Table XI contains the principal morning and afternoon epoch of the normal value of the total force.

The morning epoch is taken from the diagrams; the afternoon epoch is computed.

TABLE XI.—EPOCHS OF NORMAL TOTAL FORCE.

1841—1845.	A. M.	P. M.
January	9^h	$4^h\ 02^m$
February	7	5 16
March	8½	4 51
April	5½	6 15
May	5½	6 22
June	6¼	6 07
July	5¾	6 13
August	7¼	6 03
September	8	6 35
October	not reached	4 18
November	7¾	4 48
December	not reached	3 42
Summer	6.5	6 15
Winter	7.4	4 35
Year	6.6	5 38

Annual Inequality of the Dip and Total Force.—The differences of the monthly normals, expressed in parts of the horizontal force, have been taken from Table XII of Part V. The mean of the October and December values, however, has been substituted for the November value, which produced a correction of +0.00004 to each monthly value to balance the annual sum. The approximate values of the annual inequality of the vertical force are extracted from Part VIII, after converting the scale divisions into parts of the vertical force.

Table XII contains the values of the annual inequality for the horizontal and vertical components, and, by combination, that of the dip and total force.

TABLE XII.

	$\frac{\Delta X}{X}$	$\frac{\Delta Y}{Y}$	$\Delta\theta$	$\frac{\Delta\phi}{\phi}$
January	—0.00045	—0.00003	+0.'4	—0.00008
February	—0.00015	—0.00053	—0.4	—0.00050
March	+0.00023	0.00000	—0.2	+0.00002
April	—0.00003	—0.00003	0.0	—0.00003
May	+0.00039	+0.00036	0.0	+0.00036
June	+0.00006	+0.00053	+0.5	+0.00049
July	+0.00043	+0.00017	—0.3	+0.00019
August	+0.00005	+0.00020	+0.2	+0.00019
September	—0.00020	—0.00020	0.0	—0.00020
October	—0.00013	—0.00013	0.0	—0.00013
November	—0.00012	—0.00040	—0.3	—0.00037
December	—0.00011	—0.00003	+0.1	—0.00004

From what has been said of the annual inequality of the horizontal and vertical force, it could not be expected that this inequality should appear in any decided manner in the dip and total force. With reference to the dip, all that can be concluded is, that the inequality probably does not exceed half a minute. At Toronto, where the dip is greater, it is between 0.′8 and 0.′9; lower in June and July than in January and December; range 1.′7. With respect to the total force, the inequality seems to be about 0.0003 parts of the force, which gives nearly the same range as that found at Toronto, with this difference, however, that at Philadelphia the force is greater in the summer months and less in the winter months, the reverse of what has been found at the other station.

The next and last part of the discussion of the Girard College Magnetic Observations will contain the absolute values of the magnetic declination, dip and intensity.

PART XII.

DISCUSSION

OF THE

MAGNETIC INCLINATION, AND TABLE OF ABSOLUTE VALUES OF THE DECLINATION, INCLINATION, AND INTENSITY BETWEEN 1841 AND 1845.

RESULTS AND DISCUSSION

OF THE

OBSERVATIONS FOR MAGNETIC INCLINATION, TAKEN AT GIRARD COLLEGE, PHILADELPHIA, IN 1842, 1843, AND 1844.

THE dip circle was made by Robinson, of London, in 1836, and is six inches in diameter.[1] The needles used are No. 1 and No. 2, and the poles were reversed in each set of observations. The ends of the needles are marked A and B. The instrument was mounted upon a marble pier, about twenty feet to the southeast of the Observatory.

The observations for dip were made once each week, and were commenced in January, 1842; they terminate in July, 1844. There are some interruptions, however, in the series of observation, as will be noticed in looking over the results of Table No. 1. This table contains an abstract of the results taken directly from the record; it has also been compared with the synopsis of the resulting dips in Volume III of the Record. The time is observatory mean time counted for convenience from 0^h to 24^h. Each mean result consists of 24 separate measures, with face of instrument west and east; marked side of the needle west and east, and with polarity north and south. Three readings have been taken in each position of face of the needle. With but a few exceptions, needle No. 1 was employed throughout the series; in the exceptional cases, where needle No. 2, or one of the Lloyd needles No. 1 or No. 3 were used, special corrections to refer their indications to the result by needle No. 1 have been deduced and applied.

TABLE I.—ABSTRACT OF RESULTS OF MAGNETIC DIP OBSERVED AT GIRARD COLLEGE OBSERVATORY BETWEEN 1842 AND 1844.

Year.	Month.	Day.	Hour.	Minute.	Dip. Needle No. 1.			Mean monthly dip.
					A north.	B north.	Mean.	
1842	January	4	10	0	71° 56.′4	71° 55.′2	71° 55.′8	71° 57.′5
		11	10	0	71 58.6	71 53.6	56.1	
		18	10	0	72 00.9	71 55.0	57.9	
		25	10	0	71 56.3	71 04.4	60.3	
	February	1	10	0	72 01.9	71 57.1	59.5	71 58.4
		8	10	0	72 03.6	71 55.1	59.4	
		15	10	0	71 58.0	71 53.2	55.6	
		22	10	0	72 02.0	71 56.7	59.3	

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[1] It is the same instrument with which I made the observations at stations in Europe (Amer. Phil. Trans. Vol. VII, Part I, 1840), and those in the magnetic survey of Pennsylvania, in 1840 and 1841, and at other stations farther northward and eastward, in 1843.

Year.	Month.	Day.	Hour.	Minute.	Dip. Needle No. 1.			Mean monthly dip.
					A north.	B north.	Mean.	
1842	March	1	10	0	72° 08.′1	71° 49.′5	71° 58.′8	71° 59.′5
		8	10	0	72 04.6	71 51.0	57.8	
		15	10	0	72 07.5	71 52.7	60.1	
		22	10	0	72 08.2	71 55.7	62.0	
		29	10	0	72 02.6	71 54.9	58.7	
	April	5	10	0	71 46.4	71 55.5	51.0	71 59.0
		12	10	30	72 06.2	71 57.0	61.6	
		19	9	35	72 08.5	71 55.3	61.9	
		26	9	58	72 10.5	71 52.4	61.4	
	May	3	10	19	72 11.4	71 56.1	63.7	71 61.3
		17	9	29	72 09.4	71 59.4	64.4	
		17	10	43	71 54.2	72 02.6	[1] 58.4 + 1.7	
		24	10	0	72 11.6	71 51.3	61.4	
		31	10	1	72 06.7	71 48.9	57.8	
	June	7	10	15	72 11.8	71 53.4	62.6	71 60.7
		14	9	46	72 09.1	71 52.9	61.0	
		21	9	56	71 57.1	71 59.1	58.1	
		28	9	24	72 07.8	71 54.3	61.0	
	July	13	9	11	72 10.2	71 58.3	64.3	71 57.2
		19	9	52	71 54.2	71 53.1	53.6	
		26	9	34	71 49.2	71 57.9	53.6	
	August	3	9	42	72 01.4	72 00.5	61.0	71 60.2
		9	10	1	72 06.3	71 53.5	59.9	
		16	9	57	72 04.2	71 54.8	59.5	
		30	9	40	72 05.0	71 56.2	60.6	
	September	6	9	4	72 10.0	71 58.7	64.3	71 61.2
		13	9	55	71 56.7	71 58.8	57.8	
		27	9	43	72 08.6	71 54.6	61.6	
	October	4	10	12	72 07.0	71 55.4	61.2	71 60.6
		11	10	8	72 06.4	71 55.6	61.0	
		11	11	17	71 51.3	72 03.2	[1] 57.2 + 1.7	
	November	1	10	6	72 11.9	72 01.5	66.7	71 64.1
		15	9	48	72 08.3	71 52.3	60.3	
		22	10	13	72 13.3	71 57.1	65.2	
	December	27	9	16	72 08.2	71 55.3	61.7	71 61.7
1843	April	11	10	53	71 58.0	71 42.5	71 50.3	71 54.9
		18	13	10	72 08.2	71 48.9	58.5	
		25	10	0	71 59.7	71 52.0	55.8	
	May	2	9	40	72 11.7	71 44.7	58.2	71 63.2
		9	9	25	72 11.8	72 08.2	70.0	
		16	10	22	72 00.3	72 14.9	67.6	
		23	9	50	71 59.2	72 12.9	66.1	
		30	9	55	72 05.6	71 42.7	54.1	
	June	6	10	22	72 09.5	71 54.5	62.0	71 57.7
		13	10	20	72 10.7	71 57.8	64.2	
		20	10	5	71 56.5	71 45.4	51.0	
		27	9	55	71 58.8	71 48.2	53.5	
	July	4	10	25	72 01.4	71 56.3	58.8	71 57.5
		11	10	35	72 07.9	71 44.3	56.1	
		18	10	5	72 04.9	71 51.5	58.2	
		18	11	20	71 58.8	71 55.5	[1] 57.2 + 1.7	
		20	16	37	[2]71 56.2 +1.9	[3]71 45.3 +10.0	56.7	
	August	22	10	5	[4]71 53.4 +4.3	[5]72 12.3 — 1.8	64.1	71 60.5
		24	11	17	72 02.0	71 50.7	56.3	
		24	12	0	72 01.6	72 00.2	[1] 60.9 + 1.7	
		26	17	46	[2]71 54.0 +1.9	[3]71 51.2 +10.0	58.6	
		29	10	25	72 05.1	71 55.5	60.3	
		29	11	55	[2]71 56.3 +1.9	[3]71 50.3 +10.0	59.3	

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[1] Needle No. 2.
[2] Lloyd needle No. 1, A end north.
[3] Lloyd needle No. 3, A end north.
[4] Needle No. 1, B end north.
[5] Needle No. 2, B end north.

Year.	Month.	Day.	Hour.	Minute.	Dip. Needle No. 1. A north.	Dip. Needle No. 1. B north.	Dip. Needle No. 1. Mean.	Mean monthly dip.
1843	September	5	9	42	72° 07.′3	71° 52.′0	71° 59.′6	71° 60.′7
		5	11	12	[2]71 58.9	[3]71 49.3	60.0	
					+ 1.9	+10.0		
		12	9	56	72 02.7	71 53.7	58.2	
		12	11	17	71 54.8	71 57.0	[1] 55.9	
							+ 1.7	
		12	13	5	[2]71 57.1	[3]71 48.4	58.7	
					+ 1.9	+10.0		
		19	9	40	72 02.9	71 59.6	61.3	
		26	9	52	72 04.1	72 03.1	63.6	
	October	3	9	25	71 55.2	71 49.0	52.1	71 54.8
		10	9	32	71 56.9	71 55.2	56.0	
		17	9	42	71 50.8	72 00.7	55.7	
		24	9	40	72 00.1	71 53.4	56.8	
		31	9	32	71 50.3	71 51.0	53.6	
	November	7	9	45	72 01.2	71 51.5	56.4	71 56.4
		14	10	17	72 00.7	71 57.5	59.1	
		21	10	10	72 02.1	71 47.7	54.9	
		28	10	25	72 02.5	71 48.1	55.3	
	December	5	10	20	72 01.9	71 51.7	56.8	71 57.7
		12	10	42	72 05.7	71 58.3	62.0	
		19	10	12	71 59.0	71 51.8	55.4	
		26	10	40	72 00.5	71 52.6	56.6	
1844	January	2	10	20	71 57.6	71 53.8	71° 55.′7	71 56.2
		9	9	52	72 04.0	71 54.0	59.0	
		16	10	40	72 01.2	71 52.8	57.0	
		23	10	12	71 57.8	71 50.5	54.1	
		30	10	17	71 58.9	71 51.7	55 3	
	February	6	10	25	71 59.3	71 57.9	58.6	71 59.5
		13	10	22	72 01.0	71 59.1	60.0	
		20	10	12	71 59.1	72 01.2	60.1	
		27	10	47	71 59.7	71 58.5	59.1	
	March	5	11	10	71 56.6	71 59.1	57.8	71 58.6
		12	9	56	71 56.6	71 58.7	57.7	
		19	10	22	72 01.5	72 02.2	61.9	
		26	9	55	71 58.6	71 55.3	57.0	
	April	2	10	57	72 04.1	71 52.7	58.4	71 55.9
		9	10	1	71 55.2	71 54.8	55.0	
		16	10	7	71 59.1	71 55.9	57.5	
		23	10	18	71 55.7	71 49.4	52.6	
		30	9	55	72 00.6	71 51.5	56.1	
	May	7	9	50	71 57.2	71 54.5	55.8	71 57.1
		14	9	49	71 59.0	71 54.4	56.7	
		21	10	9	71 57.5	71 57.0	57.3	
		28	9	50	71 59.5	71 57.6	58.5	
	June	18	11	47	71 59.5	71 55.1	57.3	71 57.3
	July	4	12	53	71 56.5	71 56.6	56.6	71 58.9
		16	10	37	72 02.1	72 06.7	64.4	
		23	10	48	71 56.3	71 57.7	57.0	
		30	10	40	72 00.4	71 54.8	57.6	

Determination of corrections to results by needle No. 2, by Lloyd needles Nos. 1 and 3, and for want of reversal of polarity for needles Nos. 1 and 2 on August 22, 1843. Needle No. 1 being that ordinarily used, the exceptional readings with the other three needles have been referred to the indications of needle No. 1.

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[1] Needle No. 2.

[2] Lloyd needle No. 1, A end north.

[3] Lloyd needle No. 3, A end north.

The index error to needle No. 2 we find by direct comparison with needle No. 1 on the following dates:—

May 17, 1842	correction +6.'0	Mean +1.'7
October 11, 1842	" +3.8	
July 18, 1843	" +1.0	
August 24, 1843	" —4.6	
September 12, 1843	" +2.3	

The correction to the Lloyd needles No. 1 and No. 3, A end north, we obtain also by direct comparison, viz:—

August 29, 1843, correction to Lloyd No. 1,	+4.'0	to Lloyd No. 3, +10.'0
September 5, 1843, " " "	+0.7	" " +10.3
September 12, 1853, " " "	+1.1	" " + 9.8
Mean correction,	+1.9	" " +10.00

The corrections for polarity to needles 1 and 2 in 1843, are determined as follows:—

For needle No. 1. Mean dip in 1843 from 34 results, A north,	71° 62.'4
" " " " " B north,	71 53.8
Mean dip	71 58.1

Hence correction to needle 1, A north, —4.'3, and B north + 4.'3

For needle No. 2 we have the following differences:—

May 17, 1842, A north —B north	— 8.'4	Mean —3.'6
October 11, 1842, " "	—11.9	
July 18, 1843, " "	+ 3.3	
August 24, 1843, " "	+ 1.4	
September 12, 1843, " "	— 2.2	

Hence correction to needle 2, A north +1.'8, B north, —1.'8

The above corrections have been applied.

Recapitulation of Monthly Means of the Inclination.

Month.	1842 71°+	1843 71°+	1844 71°+
January	57.'5	- - -	56.'2
February	58.4	- - -	59.5
March	59.5	- - -	58.6
April	59.0	54.'9	55.9
May	61.3	63.2	57.1
June	60.7	57.7	57.3
July	57.2	57.5	58.9
August	60.2	60.5	- - -
September	61.2	60.7	- - -
October	60.6	54.8	- - -
November	64.1	56.4	- - -
December	61.7	57.7	- - -
Mean	60.1	58.2	57.6

The preceding results indicate an annual diminution of the dip of 1.'2. To complete the dip for the year 1843, the values for January, February, and March have been interpolated by taking the means of 1842 and 1843 of these months respectively. The interpolated dips are 71° 56.'9, 58.'9, and 59.'0. We have the final values:—

Dip for 1842.5	72° 01.'1
" 1843.5	71 58.2
" 1844.4	71 57.6

If we divide the monthly means (inclusive of the interpolated dips for January, February, and March, 1843) into two parts, we find the values:—

From January, 1842, to April, 1843 (inclusive) . . .	71° 59.′4
" April 1843, to July, 1844 " . . .	71 57.9

The corresponding epochs are September 1, 1842, and December 1, 1843, which again give an annual decrease of 1.′2.

It is desirable, however, to extend the investigation of the annual effect of the secular change of the dip beyond the years above stated. In the Coast Survey Report for 1856,[1] Assistant Schott discussed the secular change of the dip at various places, and finds that the middle of the year 1842 (1842.7 ±0.7 years) was an epoch of minimum dip for places between Cambridge, Mass., Toronto, Canada, and Washington, D. C. The expression for the secular change for Philadelphia (page 241 of the 1856 report) is derived from 19 observations, contracted to 8 normals, between 1834 and 1855.

The dips extracted from a manuscript paper on my magnetic surveys in various parts of the Northeastern States during the years 1834–5, 1840 1841, and 1843, are as follows:—

Observed dip at Philadelphia,	July 21, 1840 . . .	71° 52.′6
" "	October 28, 1840 . . .	71 53.0
" "	April 26, 1841 . . .	72 00.6
" "	July 20, 1841 . . .	71 57.0
" "	October 9, 1841 . . .	71 58.2
" "	November 1, 1841 . . .	71 59.1

A collection and combination of all the observed values for dip at Philadelphia (as far as they have come to my notice) are given in the following table:—

Date.	Observer.	Dip.	Mean dip.	Mean epoch.
July, 1834	Prof. Bache and Prof. Courtenay	71° 60.′2	72° 00.′2	1834.5
-------- 1838	Prof. Bache	71 43.9	excluded	
September, 1839	Prof. Loomis	71 67.1	72 07.1	1839.7
July, 1840	Prof. Bache	71 52.6	71 53.0	1840.7
September, 1840	Prof. Bache	71 53.3		
October 1840	Prof. Bache	71 53.0		
March, 1841	--------------------	71 60.7	71 58.4	1841.5
April, 1841	Prof. Bache	71 58.2		
April, 1841	Prof. Bache	71 60.6		
April, 1841	Prof. Bache	71 59.0		
June, 1841	Major Graham	71 54.5		
July, 1841	Prof. Bache	71 57.0		
October, 1841	Prof. Bache	71 58.2		
November, 1841	Prof. Bache	71 59.1		
-------- 1842	Dr. Locke	71 60.1	71 59.7	1842.5
-------- 1842	Captain Lefroy	71 59.0		
January to December, 1842	Prof. Bache	71 60.1		
April to December, 1843	Prof. Bache	71 58.2	71 58.2	1843.6
-------- 1844	Major Graham	71 61.8	72 02.0	1844.3
April, 1844	Dr. Locke	71 59.3		
May, 1844	--------------------	71 69.2		
January to July, 1844	Prof. Bache	71 57.6		
May, 1846	Dr. Locke	71 61.0	72 01.0	1846.4
September, 1855	Ass't Schott	71 77.7	72 17.7	1855.7
August, 1862	Ass't Schott	71 65.8	72 05.8	1862.6

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[1] Appendix No. 32, p. 235. Discussion of the secular variation of the magnetic inclination in the Northeastern States.

The annual inequality in the dip need not here be considered, as the index error of the various needles and the observing error are much greater than the maximum amount of that inequality which, according to the Toronto observations, hardly exceeds ±1′.

Collecting the mean dips and mean epoch, and adopting the expression

$$\theta = \theta_1 + x + y\,(t - t_0) + z\,(t - t_0)^2$$

where

θ = resulting dip at any time between 1830 and 1860
θ_1 = assumed dip at epoch, x its correction, $\theta_1 = 72^\circ.00$
t_0 = epoch or 1840.0
t = any other time between the above limits.

We obtain from the following combination of the observations by the method of least squares, the values of x, y, and z.

		Mean dip.	Mean year.
Group I	3 results	72.°00	1838.3
" II	5 "	72.00	1843.5
" III	2 "	72.20	1859.2

whence $\theta = +72.^\circ00 - 0.00011\,(t - 1840) + 0.00060\,(t - 1840)^2$

The observed and computed dips compare as follows:—

Epoch.	Observed dip.	Computed dip.	Obs'd—comp'd.
1834.5	72.°00	72.°02	—0.°02
1839.7	72.12	72.00	+0.12
1840.7	71.88	72.00	—0.12
1841.5	71.97	72.00	—0.03
1842.5	72.00	72.00	0.00
1843.6	71.97	72.01	—0.04
1844.3	72.03	72.01	+0.02
1846.4	72.02	72.03	—0.01
1855.7	72.29	72.15	+0.14
1862.6	72.10	72.31	—0.21

The probable error of any one representation is ±4.′8.

The minimum dip, according to the above formula, occurred in January, 1840; at Toronto this minimum occurred in 1843.

By means of the formula we find the dip for the middle of each year:—

Year.	Computed dip.	Observed dip.	Adopted dip.
1840.5	72.°00		71° 59′
1841.5	72.00		71 59
1842.5	72.00	72.°00	72 00
1843.5	72.01	71.97	71 58
1844.5	72.01	71.97	71 58
1845.5	72.02		72 01

We may now collect in one table the numerical values of the magnetic elements as found in the preceding discussion. The units for the force are feet and grains. + indicates west declination and north dip.

Epoch.	Girard College, Philadelphia.				
	ψ	θ	X	Y	ϕ
January, 1841	+3° 23′	+71° 59′	4.178	12.05	13.51
" 1842	3 28	71 59	4.175	12.84	13.50
" 1843	3 32	71 59	4.173	12.83	13.49
" 1844	3 36	71 58	4.170	12.81	13.47
" 1845	3 41	72 00	4.168	12.83	13.49
Mean: January, 1843	+3 32	+71 59	4.173	12.83	13.49

The latitude of the Observatory is	39° 58′.4
And its longitude west of Greenwich	75 10.1
Or, in time	5h 00m 40.s3

SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.
180

ON THE CONSTRUCTION
OF A
SILVERED GLASS TELESCOPE,
FIFTEEN AND A HALF INCHES IN APERTURE,
AND
ITS USE IN CELESTIAL PHOTOGRAPHY.

BY
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[ACCEPTED FOR PUBLICATION, JANUARY, 1864.]

COMMISSION

TO WHICH THIS PAPER HAS BEEN REFERRED.

Prof. Wolcott Gibbs.
Com. J. M. Gilliss, U. S. N.

Joseph Henry,
Secretary S. I.

COLLINS, PRINTER,
PHILADELPHIA.

CONTENTS.

HISTORICAL SKETCH OF THE TELESCOPE. MEMOIR DIVIDED INTO SIX SECTIONS:—

AN ACCOUNT

OF

THE CONSTRUCTION AND USE OF A SILVERED GLASS TELESCOPE.

THE construction of a reflecting telescope capable of showing every celestial object now known, is not a very difficult task. It demands principally perseverance and careful observation of minutiæ. The cost of materials is but trifling compared with the result obtained, and I can see no reason why silvered glass instruments should not come into general use among amateurs. The future hopes of Astronomy lie in the multitude of observers, and in the concentration of the action of many minds. If what is written here should aid in the advance of that noble study, I shall feel amply repaid for my labor.

A short historical sketch of this telescope may not be uninteresting. In the summer of 1857, I visited Lord Rosse's great reflector, at Parsonstown, and, in addition to an inspection of the machinery for grinding and polishing, had an opportunity of seeing several celestial objects through it. On returning home, in 1858, I determined to construct a similar, though smaller instrument; which, however, should be larger than any in America, and be especially adapted for photography. Accordingly, in September of that year, a 15 inch speculum was cast, and a machine to work it made. In 1860, the observatory was built, by the village carpenter, from my own designs, at my father's country seat, and the telescope with its metal speculum mounted. This latter was, however, soon after abandoned, and silvered glass adopted. During 1861, the difficulties of grinding and polishing that are detailed in this account were met with, and the remedies for many of them ascertained. The experiments were conducted by the aid of three 15½ inch disks of glass, together with a variety of smaller pieces. Three mirrors of the same focal length and aperture are almost essential, for it not infrequently happens that two in succession will be so similar, that a third is required for attempting an advance beyond them. One of these was made to acquire a parabolic figure, and bore a power of 1,000. The winter was devoted to perfecting the art of silvering, and to the study of special photographic processes. A large portion of 1862 was spent with a regiment in a campaign in Virginia, and but few photographs were produced till autumn, when sand clocks and clepsydras of several kinds having been made, the driving mechanism attained great excellence. During the winter, the art of local corrections was acquired, and two 15½ inch mirrors, as well as two of 9 inches for the photographic enlarging apparatus, were completed. The greater part of 1863 has been occupied by lunar and planetary photography, and the enlargement of the small negatives obtained at the focus of the great reflector. Lunar negatives have been produced which have been magnified to 3 feet in diameter. I have also finished two mirrors $15\frac{1}{2}$ inches in aperture, suitable for a Herschelian telescope, that is, which can only converge oblique pencils to a focus free from aberration. This work has all been accomplished in the intervals of professional labor.

The details of the preceding operations are arranged as follows: § 1. GRINDING AND POLISHING THE MIRRORS; § 2. THE TELESCOPE MOUNTING; § 3. THE CLOCK MOVEMENT; § 4. THE OBSERVATORY; § 5. THE PHOTOGRAPHIC LABORATORY; § 6. THE PHOTOGRAPHIC ENLARGER.

§ 1. GRINDING AND POLISHING THE MIRRORS.

(1.) EXPERIMENTS ON A METAL SPECULUM.

My first 15 inch speculum was an alloy of copper and tin, in the proportions given by Lord Rosse. His general directions were closely followed, and the casting was very fine, free from pores, and of silvery whiteness. It was 2 inches thick, weighed 110 pounds, and was intended to be of 12 feet focal length. The grinding and polishing were conducted with the Rosse machine. Although a great amount of time was spent in various trials, extending over more than a year, a fine figure was never obtained—the principal obstacle to success being a tendency to polish in rings of different focal length. It must, however, be borne in mind that Lord Rosse had so thoroughly mastered the peculiarities of his machine as to produce with it the largest specula ever made and of very fine figure.

During these experiments there was occasion to grind out some imperfections, $\frac{8}{100}$ of an inch deep, from the face of the metal. This operation was greatly assisted by stopping up the defects with a thick alcoholic solution of Canada balsam, and having made a rim of wax around the edge of the mirror, pouring on nitro-hydrochloric acid, which quickly corroded away the uncovered spaces. Subsequently an increase in focal length of 15 inches was accomplished, by attacking the edge zones of the surface with the acid in graduated depths.

An attempt also was made to assist the tedious grinding operation by including the grinder and mirror in a Voltaic circuit, making the speculum the positive pole. By decomposing acidulated water between it and the grinder, and thereby oxidizing the tin and copper of the speculum, the operation was much facilitated, but the battery surface required was too great for common use. If a sufficient intensity was given to the current, speculum metal was transferred without oxidation to the grinder, and deposited in thin layers upon it. It was proposed at one time to make use of this fact, and coat a mirror of brass with a layer of speculum metal by electrotyping. The gain in lightness would be considerable.

During the winter of 1860 the speculum was split into two pieces, by the expansion in freezing of a few drops of water that had found their way into the supporting case.

(2.) SILVERING GLASS.

At Sir John Herschel's suggestion (given on the occasion of a visit that my father paid him in 1860), experiments were next commenced with silvered glass specula. These were described as possessing great capabilities for astronomical purposes. They reflect more than 90 per cent. of the light that falls upon them, and only weigh one-eighth as much as specula of metal of equal aperture.

As no details of Steinheil's or Foucault's processes for silvering in the cold way were accessible at the time, trials extending at intervals over four months were made. A variety of reducing agents were used, and eventually good results obtained with milk sugar.

Soon after a description of the process resorted to by M. Foucault in his excellent experiments was procured. It consists in decomposing an alcoholic solution of ammonia and nitrate of silver by oil of cloves. The preparation of the solutions and putting them in a proper state of instability are very difficult, and the results by no means certain. The silver is apt to be soft and easily rubbed off, or of a leaden appearance. It is liable to become spotted from adherent particles of the solutions used in its preparation, and often when dissolved off a piece of glass with nitric acid leaves a reddish powder. Occasionally, however, the process gives excellent results.

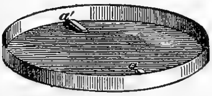
In the winter of 1861, M. Cimeg published his method of silvering looking-glasses by tartrate of potash and soda (Rochelle salt). Since I have made modifications in it fitting the silver for being polished on the reverse side, I have never on any occasion failed to secure bright, hard, and in every respect, perfect films.

The operation, which in many details resembles that of M. Foucault, is divided into: 1st, cleaning the glass; 2d, preparing the solutions; 3d, warming the glass; 4th, immersion in the silver solution and stay there; 5th, polishing. It should be carried on in a room warmed to 70° F. at least. The description is for a 15½ inch mirror.

1st. Clean the glass like a plate for collodion photography. Rub it thoroughly with nitric acid, and then wash it well in plenty of water, and set it on edge on filtering paper to dry. Then cover it with a mixture of alcohol and prepared chalk, and allow evaporation to take place. Rub it in succession with many pieces of cotton flannel. This leaves the surface almost chemically clean. Lately, instead of chalk I have used plain uniodized collodion, and polished with a freshly-washed piece of cotton flannel, as soon as the film had become semi-solid.

2d. Dissolve 560 grains of Rochelle salt in two or three ounces of water and filter. Dissolve 800 grains of nitrate of silver in four ounces of water. Take an ounce of strong ammonia of commerce, and add nitrate solution to it until a brown precipitate remains undissolved. Then add more ammonia and again nitrate of silver solution. This alternate addition is to be carefully continued until the silver solution is exhausted, when some of the brown precipitate should remain in suspension. The mixture then contains an undissolved excess of oxide of silver. Filter. Just before using, mix with the Rochelle salt solution, and add water enough to make 22 ounces.

Fig. 1.



The Silvering Vessel.

The vessel in which the silvering is to be performed may be a circular dish (Fig. 1) of ordinary tinplate, 16½ inches in diameter, with a flat bottom and perpendicular sides one inch high, and coated inside with a mixture of beeswax and rosin (equal parts). At opposite ends of one diameter two narrow pieces of wood, *a a′*, ⅛ of an inch thick, are cemented. They are to keep the face of the mirror from the bottom of the vessel, and permit of a rocking motion being given to the glass. Before using such a vessel, it is necessary to touch any cracks that may have formed in the wax with a hot poker. A spirit lamp causes bubbles and holes through to the tin. The vessel too must always, especially if partly silvered, be cleaned with nitric acid and water, and left filled with cold water till needed. Instead of the above, India-rubber baths have been occasionally used.

3d. In order to secure fine and hard deposits in the shortest time and with weak solutions, it is desirable, though not necessary, to warm the glass slightly. This is best done by putting it in a tub or other suitably sized vessel, and pouring in water enough to cover the glass. Then hot water is gradually stirred in, till the mixture reaches 100° F. It is also advantageous to place the vessels containing the ingredients for the silvering solution in the same bath for a short time.

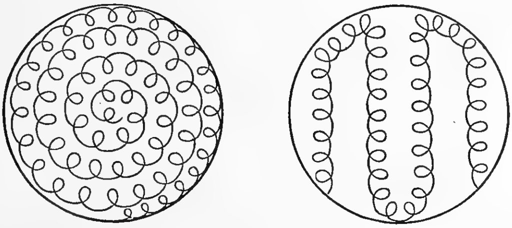
4th. On taking the glass out of the warm water, carry it to the silvering vessel—into which an assistant has just previously poured the mixed silvering solution—and immediately immerse it face downwards, dipping in first one edge and then quickly letting down the other till the face is horizontal. The back of course is not covered with the fluid. The same precautions are necessary to avoid streaks in silvering as in the case of putting a collodion plate in the bath. Place the whole apparatus before a window. Keep up a slow rocking motion of the glass, and watch for the appearance of the bright silver film. The solution quickly turns brown, and the silver soon after appears, usually in from three to five minutes. Leave the mirror in the liquid about six times as long. At the expiration of the twenty minutes or half hour lift it out, and look through it at some very bright object. If the object is scarcely visible, the silver surface must then be washed with plenty of water, and set on edge on bibulous paper to dry. If, on the contrary, it is too thin, put it quickly back, and leave it until thick enough. When polished the silver ought, if held between the eye and the sun, to show his disk of a light blue tint. On coming out of the bath the metallic surface should have a rosy golden color by reflected light.

5th. When the mirror is thoroughly dry, and no drops of water remain about the edges, lay it upon its back on a thoroughly dusted table. Take a piece of the softest thin buckskin, and stuff it loosely with cotton to make a rubber. Avoid using the edge pieces of a skin, as they are always hard and contain nodules of lime.

Go gently over the whole silver surface with this rubber in circular strokes, in order to commence the removal of the rosy golden film, and to condense the silver. Then having put some very fine rouge on a piece of buckskin laid flat on the table, impregnate the rubber with it. The best stroke for polishing is a motion in small circles, at times going gradually round on the mirror, at times across on the various chords (Fig. 2). At the end of an hour of continuous gentle rubbing, with occasional touches on the flat rouged skin, the surface will be polished so as to be perfectly black in oblique positions, and, with even moderate care, scratchless.

The process is like a burnishing. Put the rubber carefully away for another occasion.

Fig. 2.



Polishing Strokes.

The thickness of the silver thus deposited is about $\frac{1}{200,000}$ of an inch. Gold leaf, when equally transparent, is estimated at the same fraction. The actual value of the amount on a 15½ inch mirror is not quite a cent—the weight being less than 4 grains (239 milligrammes on one occasion when the silver was unusually thick), if the directions above given are followed.

Variations in thickness of this film of silver on various parts of the face of the mirror are consequently only small fractions of $\frac{1}{200,000}$ of an inch, and are therefore of no optical moment whatever. If a glass has been properly silvered, and shows the sun of the same color and intensity through all parts of its surface, the most delicate optical tests will certainly fail to indicate any difference in figure between the silver and the glass underneath. The faintest peculiarities of local surface seen on the glass by the method of M. Foucault, will be reproduced on the silver.

The durability of these silver films varies, depending on the circumstances under which they are placed, and the method of preparation. Sulphuretted hydrogen tarnishes them quickly. Drops of water may split the silver off. Under certain circumstances, too, minute fissures will spread all over the surface of the silver, and it will apparently lose its adhesion to the glass. This phenomenon seems to be connected with a continued exposure to dampness, and is avoided by grinding the edge of the concave mirror flat, and keeping it covered when not in use with a sheet of flat plate glass. Heat seems to have no prejudicial effect, though it might have been supposed that the difference in expansibility would have overcome the mutual adhesion.

Generally silvered mirrors are very enduring, and will bear polishing repeatedly, if previously dried by heat. I have some which have been used as diagonal reflectors in the Newtonian, and have been exposed during a large part of the day to the heat of the sun concentrated by the 15½ inch mirror. These small mirrors are never covered, and yet the one now in the telescope has been there a year, and has had the dusty film—like that which accumulates on glass—polished off it a dozen times.

In order to guard against tarnishing, experiments were at first made in gilding silver films, but were abandoned when found to be unnecessary. A partial conversion of the silver film into a golden one, when it will resist sulphuretted hydrogen, can be accomplished as follows: Take three grains of hyposulphite of soda, and dissolve it in an ounce of water. Add to it slowly a solution in water of one grain of chloride of gold. A lemon yellow liquid results, which eventually becomes clear. Immerse the silvered glass in it for twenty-four hours. An exchange will take place, and the film become yellowish. I have a piece of glass prepared in this way which remains unhurt in a box, where other pieces of plain silvered glass have changed some to yellow, some to blue, from exposure to coal gas.

I have also used silvered glass plates for daguerreotyping. They iodize beautifully if freshly polished, and owing probably to the absence of the usual copper alloy of silver plating, take impressions with very short exposures. The resulting picture has a rosy warmth, rarely seen in ordinary daguerreotypes. The only precaution necessary is in fixing to use an alcoholic solution of cyanide of potassium, instead of hyposulphite of soda dissolved in water. The latter has a tendency to split up the silver. The subsequent washing must be with diluted common alcohol.

Pictures obtained by this method will bear high magnifying powers without showing granulation. Unfortunately the exposure required for them in the telescope is six times as great as for a sensitive wet collodion, though the iodizing be carried to a lemon yellow, the bromizing to a rose red, and the plate be returned to the iodine.

(3.) Grinding and Polishing Glass.

Some of the facts stated in the following paragraphs, the result of numerous experiments, may not be new to practical opticians. I have had, however, to polish with my own hands more than a hundred mirrors of various sizes, from 19 inches to $\frac{1}{4}$ of an inch in diameter, and to experience very frequent failures for three years, before succeeding in producing large surfaces with certainty and quickly. It is well nigh impossible to obtain from opticians the practical minutiæ which are essential, and which they conceal even from each other. The long continued researches of Lord Rosse, Mr. Lassell, and M. Foucault are full of the most valuable facts, and have been of continual use.

The subject is divided into: a. The Peculiarities of Glass; b. Emery and Rouge; c. Tools of Iron, Lead and Pitch; d. Methods of Examining Surfaces; e. Machines.

a. *Peculiarities of Glass.*

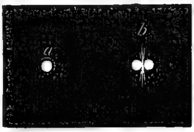
Effects of Pressure.—It is generally supposed that glass is possessed of the power of resistance to compression and rigidity in a very marked manner. In the course of these experiments it has appeared that a sheet of it, even when very thick, can with difficulty be set on edge without bending so much as to be optically worthless. Fortunately in every disk of glass that I have tried, there is one diameter on either end of which it may stand without harm.

In examining lately various works on astronomy and optics, it appears that the same difficulty has been found not only in glass but also in speculum metal. Short used always to mark on the edge of the large mirrors of his Gregorian telescopes the point which should be placed uppermost, in case they were removed from their cells. In achromatics the image is very sensibly changed in sharpness if the flint and crown are not in the best positions; and Mr. Airy, in mounting the Northumberland telescope, had to arrange the means for turning the lenses on their common axis, until the finest image was attained. In no account, however, have I found a critical statement of the exact nature of the deformation, the observers merely remarking that in some positions of the object glass there was a sharper image than in others.

Before I appreciated the facts now to be mentioned, many fine mirrors were condemned to be re-polished, which, had they been properly set in their mountings, would have operated excellently.

In attempting to ascertain the nature of deformations by pressure, many changes were made in the position of the disk of glass, and in the kind of support. Some square mirrors, too, were ground and polished. As an example of the final results, the following case is presented: A $15\frac{1}{2}$ inch unsilvered mirror $1\frac{1}{4}$ inch thick was set with its best diameter perpendicular, the axis of the mirror being horizontal (Fig. 8). The image of a pin-hole illuminated by a lamp was then observed to be single, sharply defined, and with interference rings surrounding it as at *a*, Fig. 3. On turning the glass 90 degrees, that is one quarter way round, its axis still pointing in the same direction, it could hardly be realized that the same concave surface was converging the rays. The image was separated into two of about equal intensity, as at *b*, with a wing of light going out above and below from the junction. Inside and outside of the focal plane the cone of rays had an elliptical section, the major axis being horizontal inside, and perpendicular outside. Turning the mirror still more round the image gradually improved, until the original diameter was perpendicular again—the end that had been the uppermost now being the lowest. A similar series of changes occurred in supporting the glass on various parts of the other semicircle. It might be supposed that irregularities on the edge of the glass disk, or in the supporting arc would account for the phenomena. But two facts dispose of the former of these hypotheses: in the first place if the glass be turned exactly half way round, the character of the image is unchanged, and it is not to be believed that in many different mirrors this could occur by chance coincidence. In the second place, one of these mirrors has been carefully examined after being ground and polished three times in succession, and on each occasion required the same diameter to be perpendicular. As to the second hypothesis no material difference is observed whether the supporting arc below be large or small, nor when it is replaced by a thin semicircle of tinplate lined with cotton wool.

Fig. 3.



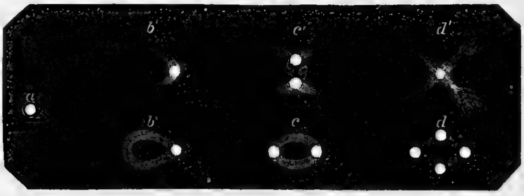
Effect of Pressure on a Reflecting Surface.

I am led to believe that this peculiarity results from the structural arrangement of the glass. The specimens that have served for these experiments have probably been subjected to a rolling operation when in a plastic state, in order to be reduced to a uniform thickness. Optical glass, which may be made by softening down irregular fragments into moulds at a temperature below that of fusion, may have the same difficulty, but whether it has a diameter of minimum compression can only be determined by experiment. Why speculum metal should have the same property might be ascertained by a critical examination of the process of casting, and the effect of the position of the openings in the mould for the entrance of the molten metal.

Effects of Heat.—The preceding changes in glass when isolated appear very simple, and their remedy, to keep the proper diameter perpendicular, is so obvious that it may seem surprising that they should have given origin to any embarrassment. In fact it is now desirable to have a disk in which they are well marked. But in practice they are complicated in the most trying manner with variations produced by heat pervading the various parts of the glass unequally. The following case illustrates the effects of heat:—

A 15½ inch mirror, which was giving at its centre of curvature a very fine image (*a*, Fig. 4) of an illuminated pin-hole, was heated at the edge by placing the right hand on the back of the mirror, at one end of the horizontal diameter. In a few seconds an arc of light came out from the image as at *b*′, and on putting the left hand on the other extremity of the same diameter the appearance *c*′ was that of two arcs of light crossing each other, and having an image at each intersection. The mirror did not recover its original condition in ten minutes. Another person on a subsequent occasion touching the ends of the perpendicular diameter at the same time that the horizontal were warmed, caused the image *d*′ to become somewhat like two of *c*′, put at right angles to each other. A little distance outside the focus the complementary appearances, *b*, *c*, *d*, were found.

Fig. 4.

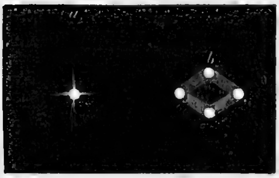


Effects of Heat on a Reflecting Surface.

By unsymmetrical warming still more remarkable forms emerged in succession, some of which were more like certain nebulæ with their milky light, than any regular geometrical figure.

If the glass had, after one of these experiments, been immediately put on the polishing machine and re-polished, the changes in surface would to a certain extent have become permanent, as in Chinese specula, and the mirror would have required either re-grinding or prolonged polishing to get rid of them. This occurred unfortunately very frequently in the earlier stages of this series of experiments, and gave origin on one occasion to a surface which could only show the image of a pin-hole as a lozenge (*b*, Fig. 5), with an image at each angle inside the focus, and as an image *a* with four wings outside

Fig. 5.



Effects of Heat rendered permanent.

But it must not be supposed that such apparent causes as these are required to disturb a surface injuriously. Frequently mirrors in the process for correction of spherical aberration will change the quality of their images without any perceptible reason for the alteration. A current of cold or warm air, a gleam of sunlight, the close approach of some person, an unguarded touch, the application of cold water injudiciously will ruin the labor of days. The avoidance of these and similar causes requires personal experience, and the amateur can only be advised to use too much caution rather than too little.

Such accidents, too, teach a useful lesson in the management of a large telescope, never, for instance, to leave one-half the mirror or lens exposed to radiate into cold space, while the other half is covered by a comparatively warm dome. Under the head of the Sun-Camera, some further facts of this kind may be found.

Oblique Mirrors.—Still another propensity of glass and speculum metal must be noted. A truly spherical concave can only give an image free from distortion when it is so set that its optical axis points to the object and returns the image directly back towards it. But I have polished a large number of mirrors in which an image free from distortion was produced *only* when oblique pencils fell on the mirror, and the image was returned along a line forming an angle of from 2 to 3 degrees with the direction of the object. Such mirrors, though exactly suited for the Herschelian construction, will not officiate in a Newtonian unless the diagonal mirror be put enough out of centre in the tube, to compensate for the figure of the mirror. Some of the best photographs of the moon that have been produced in the observatory, were made when the diagonal mirror was 6 inches out of centre in the 16 inch tube. Of course the large mirror below was not perpendicular to the axis of the tube, but was inclined 2° 32′. The figure of such a concave might be explained by the supposition that it was as if cut out of a parabolic surface of twice the diameter, so that the vertex should be on the edge. But if the mirror was turned 180° it apparently did just as well as in the first position, the image of a round object being neither oval nor elliptical, and without wings. The image, however, is never quite as fine as in the usual kind of mirrors. The true explanation seems rather to be that the radius of curvature is greater along one of the diameters than along that at right angles. How it is possible for such a figure to arise during grinding and polishing is not easy to understand, unless it be granted that glass yields more to heat and compression in one direction than another.

After these facts had been laboriously ascertained, and the method of using such otherwise valueless mirrors put in practice as above stated, chance brought a letter of Maskelyne to my notice. He says, "I hit upon an extraordinary experiment which greatly improved the performance of the six-feet reflector" . . . . . It was one made by Short. "As a like management may improve many other telescopes, I shall here relate it: I removed the great speculum from the position it ought to hold perpendicular to the axis of the tube when the telescope is said to be rightly adjusted, to one a little inclined to the same and found a certain inclination of about 2½° (as I found by the alteration of objects in the finer one of Dollond's best night glasses with a field of 6°), which caused the telescope to show the object (a printed paper) incomparably better than before; insomuch that I could read many of the words which before I could make nothing at all of. It is plain, therefore, that this telescope shows best with a certain oblique pencil of rays. Probably it will be found that this circumstance is by no means peculiar to this telescope." This very valuable observation has lain buried for eighty-two years, and ignorance of it has led to the destruction of many a valuable surface.

As regards the method of combating this tendency, it is as a general rule best to re-grind or rather re-fine the surface, for though pitch polishing has occasionally corrected it in a few minutes, it will not always do so. I have polished a surface for thirteen and a half hours, examining it frequently, without changing the obliquity in the slightest degree.

Glass, then, is a substance prone to change by heat and compression, and requiring to be handled with the utmost caution.

b. *Emery and Rouge.*

In order to excavate the concave depression in a piece of glass, emery as coarse as the head of a pin has been commonly used. This cuts rapidly, and is succeeded by finer grained varieties, till flour emery is reached. After that only washed emeries should be permitted. They are made by an elutriating process invented by Dr. Green.

Five pounds of the finest sifted flour emery are mixed with an ounce of pulverized gum arabic. Enough water to make the mass like treacle is then added, and the ingredients are thoroughly incorporated by the hand. They are put into a deep jar containing a gallon of water. After being stirred the fluid is allowed to come to rest, and the surface is skimmed. At the end of an hour the liquid containing extremely fine emery in suspension is decanted or drawn off with a siphon, nearly down to the level of the precipitated emery at the bottom, and set aside to subside in a tall vessel. When this has occurred, which will be in the lapse of a few hours, the fluid is to be carefully poured back into the first vessel, and the fine deposit in the second put into a stoppered bottle. In the same way by stirring up the precipitate again, emery that has been suspended 30, 10, 3, 1 minutes, and 20, 3, seconds is to be secured and preserved in wide-mouthed vessels.

The quantity of the finer emeries consumed in smoothing a 15½ inch surface is very trifling—a mass of each as large as two peas sufficing.

Rouge, or peroxide of iron, is better bought than prepared by the amateur. It is made by calcining sulphate of iron and washing the product in water. Three kinds are usually found in commerce: a very coarse variety containing the largest percentage of the cutting black oxide of iron, which will scratch glass like quartz; a very fine variety which can hardly polish glass, but is suitable for silver films; and one intermediate. Trial of several boxes is the best method of procuring that which is desired.

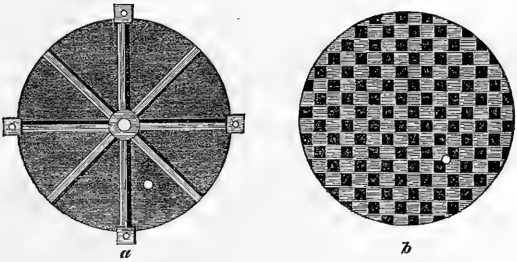
c. *Tools of Iron, Lead, and Pitch.*

In making a mirror, one of the first steps is to describe upon two stout sheets of brass or iron, arcs of a circle with a radius equal to twice the desired focal length, and to secure, by filing and grinding them together, a concave and convex gauge. When the radius bar is very long, it may be hung against the side of a house. By the assistance of these templets, the convex tools of lead and iron and the concave surface of the mirror are made parts of a sphere of proper diameter.

The excavation of a large flat disc of glass to a concave is best accomplished by means of a thick plate of lead, cast considerably more convex than the gauge. The central parts wear away very quickly, and when they become too flat must be made convex again by striking the lead on the back with a hammer. The glass is thus caused gradually to approach the right concavity. Ten or twelve hours usually suffice to complete this stage. The progress of the excavating is tested sufficiently well by setting the convex gauge on a diameter of the mirror, and observing how many slips of paper of a definite thickness will pass under the centre or edge, as the case may be. This avoids the necessity of a spherometer. The thickness of paper is found correctly enough by measuring a half ream, and dividing by the number of sheets. In this manner differences in the versed sine of a thousandth of an inch may be appreciated, and a close enough approximation to the desired focal length reached—the precision required in achromatics not being needed. The preparation of the iron tools on which the grinding is to be finished is very laborious where personal exertion is used. They require to be cast thin in order that they may be easily handled, and hence cannot be turned with very great exactness.

The pair for my large mirrors are 15½ inches in diameter, and were cast ⅜ of an inch thick, being strengthened however on the back by eight ribs ¾ of an inch high, radiating from a solid centre two inches in diameter (*a*, Fig. 6). They weighed 25 pounds apiece. Four ears, with a tapped hole in each, project at equal distances round the edge, and serve either as a means of attachment for a counterpoise lever, or as handles.

Fig. 6.



The Iron Grinder.

After these were turned and taken off the lathe chuck, they were found to be somewhat sprung, and had to be scraped and ground in the machine for a week before fitting properly. The slowness in grinding results from the emery becoming imbedded in the iron, and forming a surface as hard as adamant.

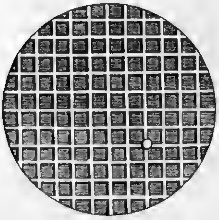
Once acquired, such grinders are very valuable, as they keep their focal length and figure apparently without change if carefully used, and only worked on glass of nearly similar curvature. At first no grooves were cut upon the face, for in the lead previously employed for fining they were found to be a fruitful source of scratches, on account of grains of emery imbedding in them, and gradually breaking loose as the lead wore away. Subsequently it appeared, that unless there was some means of spreading water and the grinding powders evenly, rings were likely to be produced on the mirror, and the iron was consequently treated as follows:—

A number of pieces of wax, such as is used in making artificial flowers, were procured. The convex iron was laid out in squares of $\frac{3}{4}$ of an inch on the side, and each alternate one being touched with a thick alcoholic solution of Canada balsam, a piece of wax of that size was put over it. This was found after many trials to be the best method of protecting some squares, and yet leaving others in the most suitable condition to be attacked. A rim of wax, melted with Canada balsam, was raised around the edge of the iron, and a pint of aqua regia poured in. In a short time this corroded out the uncovered parts to a sufficient depth, leaving an appearance like a chess-board, except that the projecting squares did not touch at the adjoining angles (*b*, Fig. 6). I should have chipped the cavities out, instead of dissolving them away, but for fear of changing the radius of curvature and breaking the thin plate. However as soon as the iron was cleaned, it proved to have become flatter, the radius of curvature having increased $7\frac{3}{4}$ inches. This shows what a state of tension and compression there must be in such a mass, when the removal of a film of metal $\frac{1}{50}$ of an inch thick, here and there, from one surface, causes so great a change.

When the glass has been brought to the finest possible grain on such a grinder, a polishing tool has to be prepared by covering the convex iron with either pitch or rosin. These substances have very similar properties, but the rosin by being clear affords an opportunity of seeing whether there are impurities, and therefore has been frequently used, straining being unnecessary. It is, however, too hard as it occurs in commerce, and requires to be softened with turpentine.

A mass sufficiently large to cover the iron $\frac{1}{8}$ of an inch thick is melted in a porcelain or metal capsule by a spirit lamp. When thoroughly liquid the lamp is blown out, and spirits of turpentine added, a drachm or two at a time. After each addition a chisel or some similar piece of metal is dipped into the fluid rosin, and then immersed in water at the temperature of the room. After a minute or two it is taken out, and tried with the thumb-nail. When the proper degree of softness is obtained, an indentation can be made by a moderate pressure.

Fig. 7.



The Polishing Tool.

The iron having been heated in hot water is then painted in stripes $\frac{1}{8}$ of an inch deep with this resinous composition. The glass concave to be polished being smeared with rouge, is pressed upon it to secure a fit, and the iron is then put in cold water. With a narrow chisel straight grooves are made, dividing the surface into squares of one inch, separated by intervals of one-quarter of an inch (Fig. 7). Under certain circumstances it is also desirable to take off every other square, or perhaps reduce the polishing surface irregularly here and there, to get an excess of action on some particular portion of the mirror.

It is well, on commencing to polish with a tool made in this way, to warm the glass as well as the tool in water (page 4) before bringing the two in contact. If this is not done the polishing will not go on kindly, a good adaptation not being secured for a length of time, and the glass surface being injured at the outset. The rosin on a polisher put away for a day or two suffers an internal change, a species of irregular swelling, and does not retain its original form. Heating, too, has a good effect in preventing disturbance by local variations of temperature in the glass.

The description of "Local Polishers" will be given under *Machines*.

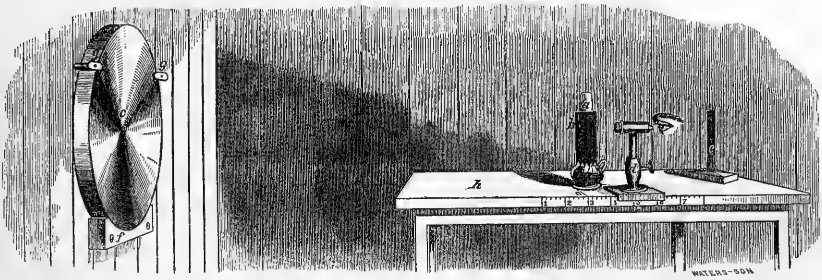
d. *Methods of Examining Surfaces.*

I have been in the habit of testing mirrors exclusively at the centre of curvature, not putting them in the telescope tube until nearly parabolic or finished. The means of trial are so excellent, the indications obtained so precise, and the freedom from atmospheric disturbances so complete, that the greatest facilities are offered for ascertaining the nature of a surface. In addition the observer is entirely independent of day or night, and of the weather. I do not think that anything more is learned of the telescope, even under favorable circumstances, than in the workshop. For the improvement of these methods of observation, Science is largely indebted to M. Foucault, whose third test—the second in the next paragraph—is sufficient to afford by itself a large part of the information required in correcting a concave surface.

There are two distinct modes of examination: 1st, observing with an eye-piece the image of an illuminated pin-hole at the focus, and the cone of rays inside and outside that plane; 2d, receiving the entire pencil of light coming from the mirror through the pupil on the retina, and noticing the distribution of light and shade, and the appearances in relief on the face of the mirror.

The arrangements for these tests are as follows: Around the flame of a lamp (*a*, Fig. 8) a sheet of tin is bent so as to form a cylindrical screen. Through it at the height of the brightest part of the flame, as at *b*, two holes are bored, a quarter of an inch apart, one $\frac{1}{32}$ of an inch in diameter, the other as small as the point of the finest needle will make—perhaps $\frac{1}{200}$ of an inch. This apparatus is to be set at the centre

Fig. 8.

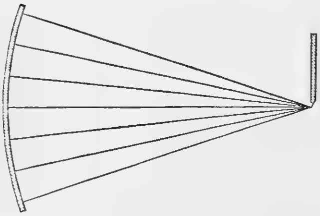


Testing a Concave at the Centre of Curvature.

of curvature of the mirror *c*—the optical axis of the latter being horizontal—and so adjusted that the light which diverges from the illuminated hole in use, may, after impinging on the concave surface of the glass, return to form an image close by the side of the tin screen. In the case of the first test, the returning rays are received into an eye-piece or microscope, *d*, magnifying 20 times, and moving upon a divided scale to and from the mirror. In the second test the eye-piece is removed away from before the eye, and a straight-edged opaque screen, *e*, is put in its place. The mirror is supported in these trials by an arc of wood *f*, lined with thick woollen stuff, and above two wooden latches, *g*, *g*, prevent it from from falling forward, but do not compress it. It is, of course, unsilvered. In the figure the table is represented very much closer to the mirror than it should be. In trials on the 15½ inch it has to be 25 feet distant.

The appearance that a truly spherical concave surface presents with the first test is: the image of the hole is sharply defined without any areola of aberration around it, and is surrounded by interference rings. Inside and outside the focus the cone of rays is exactly similar, and circular in section. It presents no trace of irregular illumination, nor any bright or dark circles. With the second test, when the eye is brought into such a position that it receives the whole pencil of reflected rays, and the opaque screen is gradually drawn across in front of the pupil, the brightness of the surface slowly diminishes, until just as the screen is cutting off the last relic of the cone of rays (Fig. 9), the mirror presents an uniform grayish tint, followed by total darkness, and gives to the eye the sensation of a plane.

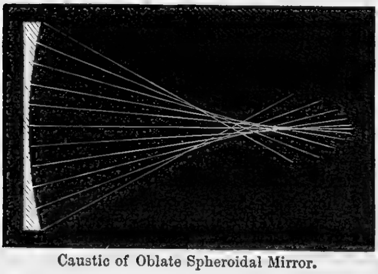
Fig. 9.



Action of the Opaque Screen.

If, however, the mirror is not spherical, but instead gradually *decreases* in focal length toward the edge, the following changes result: The image at the best focus is surrounded by a nebulosity, stronger as the deviation from the sphere is greater, and neither can a sharp focus be obtained nor interference fringes seen. In order to include this nebulosity in the image, it will be necessary to push the eye-piece toward the mirror. Before the cone of rays has completed its convergence, the mass of light will be seen to have accumulated at the periphery, and after the focus is past and divergence has commenced, the accumulation will be around the axis. That is, a caustic (Fig. 10) is formed with its summit from the mirror. By the second test, in gradually eclipsing the light coming from the mirror, just before all the rays are obstructed, a part of those which have constituted the nebulosity will escape past the screen (Fig. 11) into the eye, and cause there an extremely exaggerated appearance in relief of the solid superposed upon the

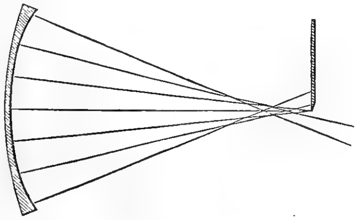
Fig. 10.



Caustic of Oblate Spheroidal Mirror.

true surface beneath. The glass will no longer seem to be a plane, but to have a section as in Fig. 12. Let us examine by the aid of M. Foucault's diagrams why it is that the surface seems thus curved. If the dotted line, Fig. 13, represents the section of the mirror, and the solid line a section of a spherical mirror of the same mean focal length, it will be seen that the curves touch at two points, but are separated by an interval elsewhere. If this interval be projected by means of the differences of the ordinates, the resulting curve will be found to be the same as that which the mirror apparently has.

Fig. 11.

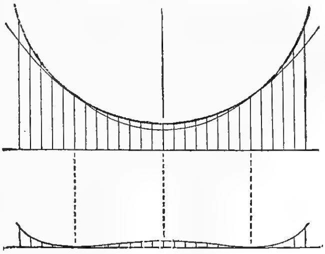


Action of the Opaque Screen.

Fig. 12.

Apparent Section of Oblate Spheroidal Mirror.

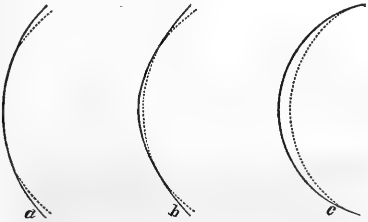
Fig. 13.



Section of Spherical and Spheroidal Mirrors.

If the opaque screen be drawn a short distance from the mirror, the appearance of the section curve will seem to change, the bottom of the groove (Fig. 12) between the centre and edge advancing inwards, and the mound in the middle growing smaller. If the screen be pushed toward the mirror the reverse takes place, the central mound becoming larger, but the edge decreasing. The reason for these variations becomes apparent by considering the three diagrams, Fig. 14. The dotted curve in each instance represents the real curve of the mirror described in the last paragraph, while the solid lines are circles drawn with radii progressionally shorter in *a*, *b* and *c*, and represent sections of three spherical mirrors whose focal lengths also progressively shorten.

Fig. 14.

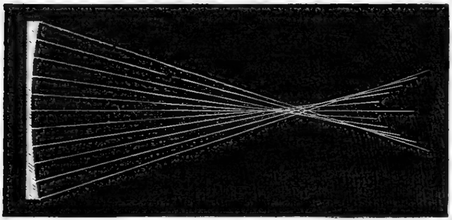


Relation of Spheres to Oblate Spheroid.

When the opaque screen is at a given distance from the mirror under examination, the only parts of the mirror which can officiate well are those which have a curvature corresponding to a radius equal to the same distance. All the other parts seem as if they were covered by projecting circular masses. In looking at Fig. 14, it is plain, then, if the opaque screen is at a maximum distance from the mirror, that the central parts alone will seem to operate, because the two curves (*a*) only touch there. If the screen is moved toward the mirror the curves (*b*) will coincide at some point between the centre and edge, while if carried still farther in only the edges touch and the appearance will be as if a large mound were fixed upon the centre. I have been careful in explaining how a surface may thus seem to present entirely different characteristics if examined from points of view which vary slightly in distance, because a knowledge of these facts is of the utmost importance in correcting such an erroneous figure. It is now obvious that the correction will be equally effectual if the mirror be polished with a small rubber on the edge, or on the centre, or partly on each. The only difference in the result will be, that the mean focal length will be increased in the first instance, and decreased in the second, while it will remain unchanged in the third.

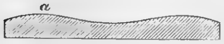
If the mirror, instead of having a section like that of an oblate spheroid, should have either an ellipse, parabola, or hyperbola, as its section curve, the appearances seen above are reversed. Whilst by the first test there is still an aberration round the image at the best focus, the eye-piece must now be drawn from the mirror to include it. The cone of rays is most dense round the axis inside, and at the periphery outside the focus, and the summit of the caustic (Fig. 15) is turned towards the mirror. The second test shows a section as in Fig. 16, a depression at the centre, and the edges turned backwards. The nature of the movement necessary to reduce the surface to a sphere is very plainly indicated, action on a zone *a* between the centre and edge. If, however, a parabolic section is required, the zone *a* must not be entirely removed, and the surface rendered apparently flat, but as much of it must be left as experience shows to be desirable.

Fig. 15.



Caustic of Hyperbolic Mirror.

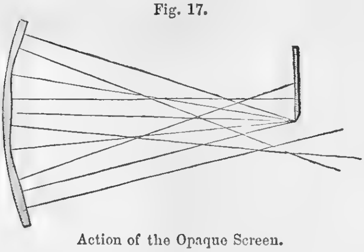
Fig. 16.



Apparent Section of Hyperbolic Mirror.

If, in still a fourth instance, the mirror is not formed by the revolution of any regular curve upon its axis, but has upon its surface zones of longer and shorter radius intermixed irregularly, a very common case, the two tests still indicate with precision the parts in fault, and the correction demanded. Thus the mirror seen in section in Fig. 17, when the principal mass of light was obstructed by the opaque screen, would still permit that coming from certain parts to find its way into the eye.

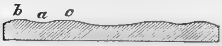
Fig. 17.



Action of the Opaque Screen.

Figure 18 represents an irregular mirror, that was produced in the process of correction of a hyperbolic surface, which had an apparent section like Fig. 16 previously. The zone *a* had been acted upon with a small local polisher, and the mirror was finished by subsequently softening down *b* and *c* with a larger tool.

Fig. 18.

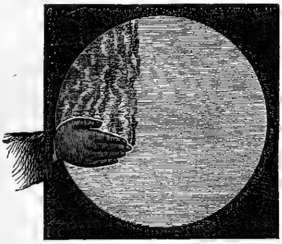


Apparent Section of Mirror with Rings.

After having gained from the preceding paragraphs a general idea of the value and nature of these tests at the centre of curvature, a more particular description of their use is desirable. M. Foucault in his methods first brings the mirror to a spherical surface, and then by moving the luminous pin-hole toward the mirror, and correspondingly retracting the eye-piece or opaque screen, carries it, avoiding aberration continually by polishing, through a series of ellipsoidal curvatures, advancing step by step toward the paraboloid of revolution. The length of the apartment, however, soon puts a termination to this gradual system of correction, and he is forced to perform the last steps of the conversion by an empirical process, and eventually to resort to trial in the telescope.

With my mirrors of 150 inches focal length, demanding from the outset a room more than 25 feet long, this successive system had to be abandoned. It was not found feasible to place the lamp in the distant focus of the ellipse—the workshop being less than 30 feet long—and putting the luminous source on stands outside, introduced several injurious complications, not the least of which was currents in the layers of variously refracting air in the apartment. In a still room the density and hygrometric variations in its various parts only give rise to slight embarrassment. The moment, however, that currents are produced, satisfactory examination of a mirror becomes difficult. The air is seen only too easily to move in great spiral convolutions between the mirror and the eye, areolæ of aberration appear around a previously excellent image, and were it not for the second test, any determination of surface would be impossible. By that test the real deviations from truth of figure can be distinguished from the atmospheric, and to a practised eye sufficient indications of necessary changes given. Such a movement as that caused by placing the hand in or under the line of the converging rays, will completely destroy the beauty of an image, and by the second test give origin in the first case to the appearance Fig. 19. In order to be completely exempt at all times from aërial difficulties, it is desirable to have control of a long underground apartment, the openings of which can be tightly closed. As no artificial warmth is needed, there is the minimum of movement in the inclosed air, and conclusions respecting a surface may be arrived at in a very short time. The mirror may also be supported from the ground, so that tremulous vibrations which weary the eye, and interfere with the accuracy of criticism, may be avoided.

Fig. 19.



Atmospheric Motions.

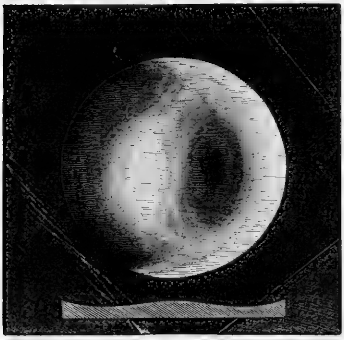
Driven then from observing an image kept continually free from aberration, through advancing ellipsoidal changes, it became necessary to study the gradual increase of deformation, produced by the greater and greater departures from a spherical surface, as the parabola was approached. It was found that a sufficient guide is still provided in these tests, by modifying them properly.

The longitudinal aberration of a mirror of small angular opening is easily calculated—being equal to the square of half the aperture, divided by eight times the principal focal length. That is, if a $15\frac{1}{2}$ inch mirror of 150 inches focal length were spherical, and were used to converge parallel rays, those from its edge would reach a focus $\frac{5}{100}$ of an inch nearer the mirror than those from its central parts. If now the converse experiment be tried, and a mirror of the same size and focal length which can converge parallel rays, falling on all its parts, to one focus, be examined at the centre of curvature, it gives there an amount of longitudinal aberration $\frac{10}{100}$ of an inch, equal to twice the preceding. This latter, then, is the condition at the centre of curvature, to which such mirror must be brought in order to converge parallel rays with exactness. In addition, strict watch must be kept upon the zones intermediate between the centre and edge, both by measurement with diaphragms of their aberration, and better yet, by observation of the regularity of the curve of that apparent solid, Fig. 16, seen by the second test.

This modification of the first test is literally a method of parabolizing by measure, and is capable of great precision when the eye learns to estimate where the exact focus of a zone is. The little irregularities found round the edges of the holes through the tin screen, Fig. 8, are in this respect of material assistance. They show, too, the increased optical or penetrating power that is gained by increase of aperture. Minute peculiarities, not visible under very high powers with a 10 inch diaphragm, become immediately perceptible even with less magnifying when the whole aperture is used, provided the mirror is spherical.

In the use of the second test precautions have to be taken, as may be inferred from page 15, to set the opaque screen exactly in the proper position. The best method for ascertaining its location is, having received the image into the eye, placed purposely too near the mirror, to cause the screen to move across the cone of rays from the right towards the left side. A jet black shadow begins to advance at the same time, and in the same direction across the mirror. If the eye is then moved from the mirror sufficiently, this black shadow can be made to originate by the same motion of the screen as before, from the left or opposite side of the mirror. Midway between these extremes there is a point where the advance is from neither side. This is the true position for the screen when it is desired to see the imperfections of the surface in highly exaggerated relief, as in Fig. 20, which represents the appearance of Fig. 12.[1]

Fig. 20.



Adjusting the Opaque Screen.

The interpretation of the lights and shadows upon the face of a mirror in this test is always easy, and the observer is not likely to mistake an elevation for a depression, if he bears in mind the fact that the surface under

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[1] In order to examine Fig. 20, the book should be held with the left side of the page toward a window or lamp. The eye should also be at least two feet distant. The centre will then be seen to protrude, and the surface present the apparent section engraved below it.

examination must always be regarded as illuminated by an oblique light coming from a source on the side opposite to that from which the screen advances, coming for instance from the left hand side, in the above description.

In practice, the diaphragms commonly used for a 15½ inch mirror have been as small as the light from the unsilvered surface would allow. A six inch aperture at the centre, a ring an inch wide round the edge, and a two inch zone midway between the two.

e. *Machines.*

In the beginning of this section the difficulties into which I fell with Lord Rosse's machine were stated. These caused it at the time to be abandoned. A machine based on the same idea as Mr. Lassell's beautiful apparatus was next constructed. It varied, however, in this, that the hypocycloidal curve was described partly by the rotation of the mirror, and partly by the motions of the polisher—the axes of the spindles carrying the two being capable either of coincidence or lateral separation to a moderate extent. A great deal of time and labor was expended in grinding and polishing numerous mirrors with it, but still the difficulty that had been so annoying in the former machine persisted. Frequently, in fact generally, from six to eight zones of unequal focal length were visible, although on some occasions when the mirror was hyperbolic, the number was reduced to two. At first it was supposed that the fault lay with the polishing, the pitch accumulating irregularly from being of improper softness, for it was found to be particularly prone to heap up at the centre. But after I had introduced a method of fine grinding with elutriated hone powder, which enabled the glass to reflect light before the pitch polishing, it became evident that the zones were connected with the mode of motion of the mechanism. Many changes were made in the speed of its various elements, and a contrivance to control the irregular motion of the polisher introduced, but a really fine and uniform parabolic surface was never obtained, the very best showing when finished zones of different focal lengths. Although it cannot be said that I have tried this machine thoroughly, for Mr. Lassell has produced specula of exquisite defining power with it, and must have avoided these imperfections to a great extent, yet the evident necessity of complicating the movement[1] considerably, to avoid the polishing in rings, led me to adopt an entirely different construction, which was used until quite recently. Although it has now been replaced by another machine, which is still better in principle, and gives fine results much more quickly, yet as it produced one parabolic surface that bore a power of more than 1000, and as it serves to introduce the process of grinding, it is worthy of description. The action of machines for grinding and polishing has been thoroughly examined in my workshop, no less than seven different ones having been made at various times.

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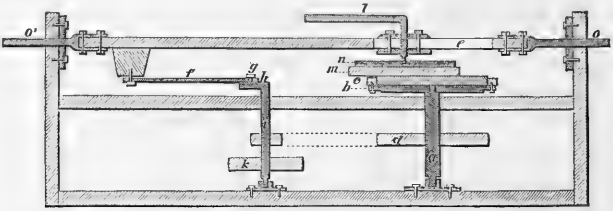
[1] Messrs. De La Rue and Nasmyth, who used one of Mr. Lassell's machines, as I have since learned, met with the same trouble, and were led to make two additions to the mechanism: 1, to control the rotation of the polisher rigorously; and 2, to give the whole speculum a lateral motion, by which the intersecting points of the curves described by the polisher were regularly changed in distance from the centre of the mirror. Mr. Lassell had previously, however, introduced a contrivance for this latter purpose himself.

The machine, which is a simplification of Lord Rosse's, was intended to give spiral strokes. It differed from the original, however, in demanding a changeable stroke, and in the absence of the lateral motion. In another most essential feature it varied from both that and Mr. Lassell's, *the mirror was always uppermost while polishing*, and being uncounterpoised escaped to as great an extent as possible from the effects of irregular pressure. To any one who has studied the deformations of a reflecting surface, and knows how troublesome it is to support a mirror properly, the advantage is apparent.

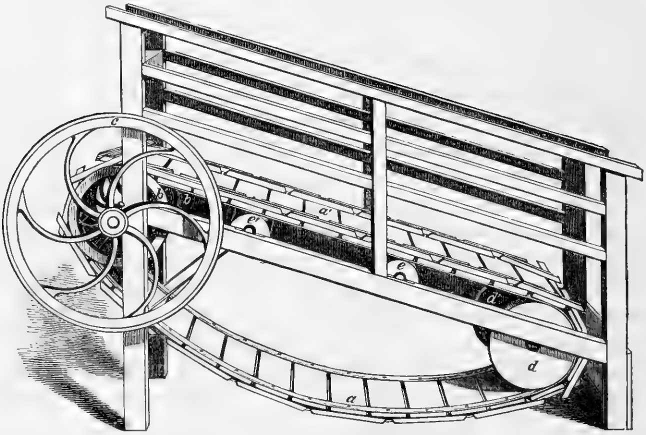
Fig. 21.



Polishing Machine.

The construction is as follows: A stout vertical shaft, *a*, Fig. 21, carries at its top a circular table *b*, upon which the polisher *c* is screwed. Below a band-wheel *d* is fixed. Above the table, at a distance of four inches, a horizontal bar *e* is arranged, so as to move back and forward in the direction of its length, and to carry with it by means of a screw *l*, the mirror *m*, and its iron back or chuck *n*. The bar is moved by a connecting rod *f*, attached to it at one end, and at the other to a pin *g* moving a slot. This slot is in a crank *h*, carried by a vertical shaft *i*, near the former one *a*. The band-wheel *k* is connected with the foot power, Fig. 22. The

Fig. 22.



The Foot Power.

machine, except those parts liable to wear by friction, is made of wood. The ends *o o′* of the horizontal bar *e*, are defended by brass tubes working in mahogany, and have even now but little shake, though many hundred thousands of reciprocations have been made.

The foot power consists of an endless band with wooden treads *a a′*, passing at one end of the apparatus over iron wheels *b b′*, which carry the band-wheel *c* upon their axle. At the other end it goes over the rollers *d d′*. Two pairs of intermediate wheels *e e′*, serve to sustain the weight of the man or animal working in it. The treads are so arranged that they interlock, and form a platform, which will not yield downwards. Owing to its inclination when a weight is put on the platform *a′*, it immediately moves from *b* toward *d* and the band-wheel turns. By a moderate exertion, equivalent to walking up a slight incline at a slow rate, a power more than sufficient to polish a 15½ inch mirror is obtained. This machine, in which very little force is lost in overcoming friction, is frequently employed for dairy use, and is moved commonly in the State of New York by a sheep. I have generally myself walked in the one used by me, and have travelled some days, during five hours, more than ten miles.

In order to give an idea of the method of using a grinding and polishing machine, the following extract from the workshop note-book is introduced:—

"A disk of plate glass 15½ inches in diameter, and 1¼ inch thick was procured. It had been polished flat on both sides, so that its internal constitution might be seen.[1] It was fastened upon the table *b* of the machine, by four blocks of wood as at *c*, Fig. 21. Underneath the glass were three thick folds of blanket, 15 inches in diameter, to prevent scratching of the lower face, and avoid risk of fracture. A convex disk of lead weighing 40 pounds having been cast, was laid upon the upper surface of the glass, and then the screw *l* was depressed so as to catch in a perforated iron plate *n*, at the back of the lead *m*, and press downward strongly.

"Emery as coarse as the head of a pin having been introduced, through a hole in the lead, motion was commenced and continued for half an hour, an occasional supply of emery being given. The machine made 150 eight-inch cross strokes, and the mirror 50 revolutions per minute. The grinder *m* was occasionally restrained from turning by the hand. At the end of the time the detritus was washed away, and an examination with the gauge made. A spot 11 inches in diameter, and $\frac{1}{60}$ of an inch deep, was found to have been ground out. The same process was continued at intervals for ten hours, measurements with the gauge being frequently made. The concave was then sufficiently deep. The leaden grinder was kept of the right convexity by beating it on the back when necessary. A finer variety of coarse emery, and after that flour emery were next put on, each for an hour. These left the surface moderately smooth, and nearly of the right focal length. The leaden grinder was then dismissed, and the iron one, Fig. 6, put in its stead. The

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[1] The glass that I have used has generally been such as was intended for dead-lights and sky-lights in ships.

mirror was removed from its place, and ground upon a large piece of flat glass for ten minutes, to produce a circular outline to the concavity. It was cemented with soft pitch to the concave iron disk, the counterpart of Fig. 6, and again recentred on the blanketed table *b*. Emeries of 3 and 20 seconds, and 1, 3, 10, 30, 60 minutes' elutriation were worked on it, an hour each. The rate of cross motion was reduced to 25 per minute to avoid heating, the mirror still revolving once for every three cross strokes. The screw pressure of *l* was stopped. This produced a surface exquisitely fine, semi-transparent, and appearing as if covered with a thin film of dried milk. It could reflect the light from objects outside the window until an incidence of 45 degrees was reached, and at night was found to be bright enough for a preliminary examination at the centre of curvature.

"The polisher was constructed in the usual way (page 12), and being smeared with rouge was fastened to the table *b*, where the mirror had been. The latter warmed in water to 120° F., was then put face downwards upon the former, and the screw *l* so lowered as to cause no pressure. The machine was allowed to make 20 four-inch cross strokes per minute, and the polisher to revolve once for every three strokes. The mirror being unconstrainedly supported on the polisher, was irregularly rotated by hand, or rather prevented from rotating with the polisher. The tendency of this method is to produce an almost spherical surface. To change it to a paraboloid, it was only necessary when the glass was polished all over to increase the length of the stroke to 8 inches, and continue working fifteen minutes at a time, examining in the intervals by the tests at the centre of curvature. The production of a polish all over occupied about two hours, but the correction of figure took more time, on account of the frequent examinations, and the absolute necessity of allowing the mirror to come back to a state of equilibrium from which it had been disturbed when worked on the machine." I have seen a mirror which was parabolic when just off the machine, by cooling over night become spherical. And these heat changes are often succeeded by other slower molecular movements, which continue to modify a surface for many days after.

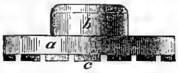
This correction, where time and not length of stroke is the governing agent, has once or twice been accomplished in fifteen minutes, but sometimes has cost several hours. If the figure should have become a hyperboloid of revolution, that is, have its edge zones too long in comparison with the centre, it is only necessary to shorten the stroke to bring it back to the sphere, or even to overpass that and produce a surface in which at the centre of curvature the edge zones have too short a focal length (Fig. 12).

Very much less trouble from zones of unequal focal length was experienced after this machine and system of working were adopted. This was owing probably partly to the element of irregularity in the rotation of the mirror, and partly to the fact that the surface is kept spherical until polished, and is then rapidly changed to the paraboloid. Where the adjustments of an apparatus are made so as to attempt to keep a surface parabolic for some hours, there is a strong tendency for zones to appear, and of a width bearing a fixed relation to the stroke.

The method of producing reflecting surfaces next to be spoken of, is however that which has finally been adopted as the best of all, being capable of forming mirrors which are as perfect as can be, and yet only requiring a short time. It is the correction of a surface by local retouches. In the account published by M. Foucault, it appears that he is in France the inventor of this improvement.

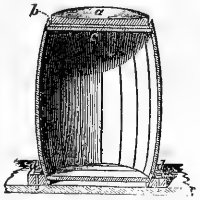
The mode of practising the retouches is as follows: Several disks of wood, as *a*, Fig. 23, varying from 8 inches to $\frac{1}{2}$ an inch in diameter, are to be provided, and covered with pitch or rosin of the usual hardness, in squares as at *c*, on one side.[1] On the other a low cylindrical handle *b*, is to be fixed. The mirror *a*, Fig. 24, having been fined with the succession of emeries before described, is laid face upward on several folds of blanket, arranged upon a circular table, screwed to an isolated post in the centre of the apartment, which permits the operator to move completely round it. An ordinary barrel has generally supplied the place of the post, the head *c*, Fig. 24, serving for the circular table, and the rim *b* preventing the mirror sliding off. The other end is fastened to the floor by four cleets *d d'*.

Fig. 23.



Local Polisher.

Fig. 24.



Section of Optician's Post.

The large polisher is first moved over the surface in straight strokes upon every chord, and a moderate pressure is exerted. As soon as the mirror is at all brightened, perhaps in five minutes, the operation is to be suspended, and an examination at the centre of curvature made. By carefully turning round, the best diameter for support is to be found, and marked with a rat-tail file on the edge, and then the curve of the mirror ascertained. If it is nearly spherical, as will be the case if the grinding has been conducted with care and irregular heating avoided, it is to be replaced on the blanketed support, and the previous action kept up until a fine polish, free from dots like stippling, is attained. This stage should occupy three or four hours. Another examination should reveal the same appearances as the preceding. It is next necessary to lengthen the radius of curvature of the edge zones, or what is much better shorten that of the centre, so as to convert the section curve into a parabola. This is accomplished by straight strokes across every diameter of the face, at first with a 4 inch, then with a 6 inch, and finally with the 8 inch polisher. Examinations must, however, be made every five or ten minutes, to determine how much lateral departure from a direct diametrical stroke is necessary, to render the curve uniform out to the edge. Care must be taken always to warm the polisher, either in front of a fire or over a spirit lamp, before using it.

Perhaps the most striking feature in this operation is that the mirror presents continually a curve of revolution, and is not diversified with undulations like a ruffle. By walking steadily round the support, on the top of which the mirror is placed, there seems to be no tendency for such irregularities to arise.

If the correction for spherical aberration should have proceeded too far, and the mirror become hyperbolic, the sphere can be recovered by working a succession

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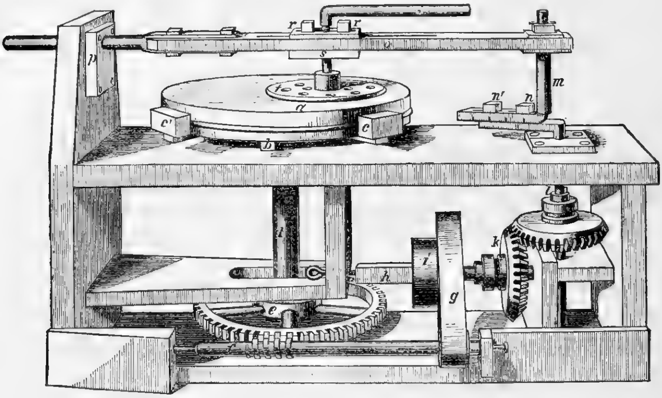
[1] M. Foucault used plano-convex lenses of glass, of a radius of curvature slightly less than that of the mirror, and covered with paper on the convex face.

of polishers of increasing size on the zone *a*, Fig. 16, intermediate between the centre and edge, causing their centres to pass along every chord that can be described tangent to the zone.

A most perfect and rapid control can thus be exercised over a surface, and an uniform result very quickly attained. It becomes a pleasant and interesting occupation to produce a mirror. But two effects have presented themselves in this operation, which unfortunately bar the way to the very best results. In the first place the edge parts of such mirrors, for more than half an inch all around, bend backwards and become of too great focal length, and the rays from these parts cannot be united with the rest forming the image. In the second place, the surface, when critically examined by the second test, is found to have a delicate wavy or fleecy appearance, not seen in machine polishing.[1] Although the variations from the true curve implied by these latter greatly exaggerated imperfections are exceedingly small, and do not prevent a thermometer bulb in the sunshine appearing like a disk surrounded by rings of interference, yet they must divert some undulations from their proper direction, or else they would not be visible. All kinds of strokes have been tried, straight, sweeping circular, hypocycloidal, &c. without effecting their removal. M. Foucault, who used a paper polisher, also encountered them. Eventually they were imputed to the unequal pressure of the hand, and in consequence a machine to overcome the two above mentioned faults of manual correction was constructed.

The mirror *a*, is carried by an iron chuck or table *b*, covered with a triple fold of blanket, and is prevented from slipping off by four cleets *c c′*. The vertical shaft *d* passes through a worm-wheel *e*, the endless screw of which *f*, is driven by a band *g*, from the primary shaft *h*. At *i* is the band-wheel for connection to

Fig. 25.



Machine for Local Corrections.

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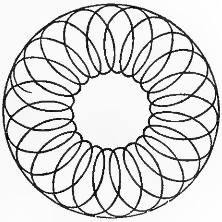
[1] By this it is not meant that there is a rippled polish, like that produced by buckskin.

the foot-power. At one end of the primary shaft is firmly fixed the cogwheel *k*, which drives the crank-shaft *l*. Attached to the horizontal part of *l*, is the crank-pin *m*. The two bolts *n n′* move in a slot, so that the crank-pin may be set at any distance from 0 to 2 inches, out of line with *l*. Above, the crank-pin carries one end of the bar *o*, the other end passing through an elliptical hole in the oak-block *p*. Down the middle of the bar runs a long slot, through which the screw-pin *q* passes, and which permits *q* to be brought over any zone from the centre to the edge of the mirror *a*. It is retained by the bolts *r r′*, which are tapped into *s*. The local polisher is seen at *t*. The curve which the centre of the local polisher describes upon the face of the mirror, varies with the adjustments. Fig. 26 is a reduction from one traced by the machine, the overlapping being seen on the left side. The mirror is not tightly confined by the cleets *c c′*, for that would certainly injure the figure, but performs a slow motion of rotation, so that in no two successive strokes are the same parts of the edge pressed against them.

Fig. 26.



Hypocycloidal Curve.

The local polishers are made of lead, alloyed with a small proportion of antimony, and are 8, 6, and 4 inches in diameter, respectively. The largest and smallest are most used, the former on account of its size polishing most quickly, but the latter giving the truest surface. The rosin that covers them is just indentable by the thumb nail, and is arranged in a novel manner. The leaden basis, as seen at *t*, Fig. 25, is perforated in many places with holes, which permit evaporation, serve for the introduction of water where needed, and allow the rosin to spread freely. Grooves are made from one aperture to another, and the rosin thus divided into irregular portions. The effects of the production of heat are in this way avoided.

The mirror may be ground and fined on this machine, in the same manner as on that described at page 21, or it may be ground with a small tool 8 inches in diameter, as recently suggested by M. Foucault, the results in the latter case being just as good a surface of revolution as in the former. It is best polished with the 8 inch, and a moderate pressure may be given by the screw *q*, if the pitch is not too soft. This, however, tends to leave an excavated place at the centre of the mirror, the size depending on the stroke of the crank *m*, which should be about 2 inches. The pin *q* ought to be half way from the centre to the edge of the mirror, but must be occasionally moved right or left an inch along the slot. When the surface is approaching a perfect polish, the warmed 4 inch polisher must be put in the place of the 8 inch. The pin *q* must be set exactly half-way between the centre and edge of the mirror, and the crank must have a stroke of two inches radius. The polisher then just goes up to the centre of the glass surface with one edge, and to the periphery with the other, while the outer excursion of the inner edge and inner excursion of the outer edge meet, and neutralize one another at a mid-way point. Wherever the edge of a polisher changes direction many times in succession, on a surface, a zone is sure to form, unless avoided in this manner. All the foregoing description is for a $15\frac{1}{2}$ inch mirror.

By this system of local polishing the difficulties of heat, distribution of polishing powders, irregular contact of the rosin, &c. that render the attainment of a fine figure so uncertain usually, entirely disappear. A spherical surface is produced as above described, and afterwards by moving q towards the edge, and at the same time increasing the stroke, it is converted into a paraboloid. The fleecy appearance spoken of on a former page is not perceived, and the surface is good almost up to the extreme edge.

(4.) Eye-Pieces, Plane Mirrors and Test Objects.

The telescope is furnished with several eye-pieces of various construction, giving magnifying powers from 75 to 1200, or if it were desired even higher. For the medium powers 300 and 600 Ramsden, or rather positive eye-pieces have been adopted. They differ, however, from the usual form in being achromatic, that is, each plano-convex is composed of a flint and crown, arranged according to formulas calculated by Littrow. In this way a large flat field and absence of color are secured, and the fine images yielded by the mirror are not injured. For the higher powers, single achromatic lenses are used, and for the highest of all a Ross microscope.

With these means it has been found that the parabolic surfaces yielded by the processes before described, will define test objects excellently. Of close double stars they will separate such as γ^2 Andromedæ, and show the colors of the components. In the case of unequal stars which seem to be more severe tests, they can show the close companion of Sirius—discovered by Mr. Alvan Clark's magnificent refractor—the sixth component of θ^1 Orionis, and a multitude of other difficult objects.

As an example of light collecting power, Debillisima between ε and 5 Lyræ is found to be quintuple, as first noticed by Mr. Lassell. In the $18\frac{1}{2}$ inch specula of Herschel, it was only recorded as double, and, according to Admiral Smyth, Lord Rosse did not notice the fourth and fifth components. Jupiter's moons show with beautiful disks, and their difference in diameter is very marked. As for the body of that planet, it is literally covered with belts up to the poles. The bright and dark spots on Venus, and the fading illumination of her inner edge, and its irregularities are perceived even when the air is far from tranquil. Stars are often seen as disks, and without any wings or tails, unless indeed the mirror should be wrongly placed, so that the best diameter for support is not in the perpendicular plane, passing through the axis of the tube.

It has been found that no advantage other than the decrease of atmospheric influence on the image, results from cutting down the aperture of these mirrors by diaphragms, while the disadvantage of reducing the separating power, is perceived at the same time. Faint objects can be better seen with the whole surface than with a reduced aperture, and this though apparently a property common to all reflectors and object glasses is not so in reality. A defective edge will often cause the whole field to be filled with a pale milky light, which will extinguish the fainter stars. Good definition is just as important for faint as for close objects.

The properties of these mirrors have been best shown by the excellence of the photographs taken with them. Although these are not as sharp as the image seen in the telescope, yet it must not be supposed that an imperfect mirror will give just as good pictures. A photograph which is magnified to 3 feet, represents a power of 380. As the original negative taken at the focus of the mirror is not quite 1½ inch in diameter when the moon is at its mean distance, it has to be enlarged about 25 times, and has therefore to be very sharp to bear it.

The light collecting power of an unsilvered mirror is quite surprising. With a 15½ inch, the companion of *a* Lyræ can be perceived, though it is only of the eleventh magnitude. The moon and other bright objects are seen with a purity highly pleasing to the eye, some parts being even more visible than after silvering.

In order to finish this description, one part more of the optical apparatus requires to be noticed—the plane mirrors. In the Newtonian reflector the image is rejected out at the side of the tube by a flat surface placed at 45° with the optical axis of the large concave.[1] If this secondary mirror is either convex or concave, it modifies the image injuriously, causing a star to look like a cross, and this though the curvature be so slight as hardly to be perceptible by ordinary means. For a long time I used a piece 3 × 5 inches, which was cut from the centre of a large looking-glass accidentally broken, but eventually found that by grinding three pieces of 6 inches in diameter against one another, and polishing them on very hard pitch, a nearer approach to a true plane could be made. They were tested by being put in the telescope, and observing whether the focus was lengthened or shortened, and also by trial on a star. When sufficiently good to bear these tests, a piece of the right size was cut out with a diamond, from the central parts.

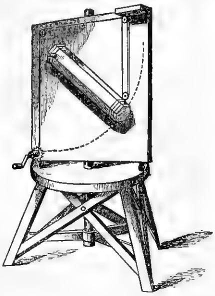
§ 2. THE TELESCOPE MOUNTING.

The telescope is mounted as an altitude and azimuth instrument, but in a manner that causes it to differ from the usual instrument of that kind. The essential feature is, that *the eye-piece or place of the sensitive plate is stationary at all altitudes*, the observer always looking straight forward, and never having to stoop or assume inconvenient and constrained positions.

The stationary eye-piece mounting was first used by Miss Caroline Herschel, who had a 27 inch Newtonian arranged on that plan. Fig. 27. (Smyth's Celestial Cycle.)

Subsequently it was applied to a large telescope by Mr. Nasmyth, the eminent engineer, but no details of his construction have reached me. He used it for making drawings of the moon, which are said to be excellently executed.

Fig. 27.



Miss Herschel's Telescope.

When it became necessary to determine how my telescope should be mounted, I was strongly urged to make it

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[1] A right-angled prism cannot be used with advantage to replace the plane silvered mirrors, because it transmits less light than they reflect, is more liable to injure the image, and the glass is apt to be more or less colored. Its great size and cost, one three inches square on two faces being required for my purposes, has also to be considered.

an equatorial. But after reflecting on the fact that it was intended for photography, and that absolute freedom from tremor was essential, a condition not attained in the equatorial when driven by a clock, and in addition that in the case of the moon rotation upon a polar axis does not suffice to counteract the motion in declination, I was led to adopt the other form.

A great many modifications of the original idea have been made. For instance, instead of counterpoising the end of the tube containing the mirror by extending the tube to a distance beyond the altitude or horizontal axis, I introduced a system of counterpoise levers which allows the telescope to work in a space little more than its own focal length across. This construction permits both ends of the tube to be supported, the lower one on a wire rope, and gives the greatest freedom from tremor, the parts coming quickly to rest after a movement. In the use of the telescope for photography, as we shall see, the system of bringing the mass of the instrument to complete rest before exposing the sensitive plate, and only driving that plate itself by a clock, is always adopted.

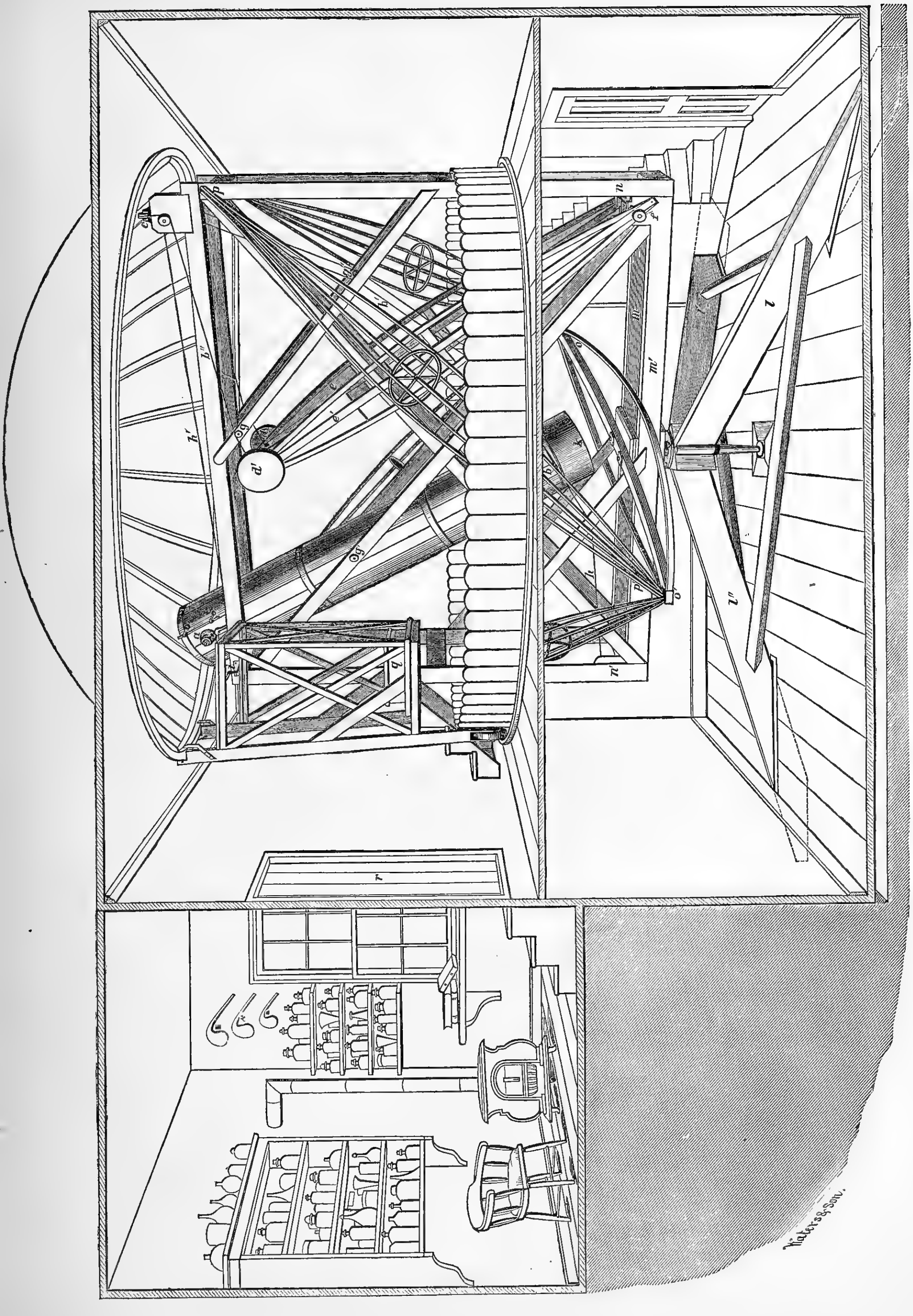
The obvious disadvantage connected with the alt-azimuth mounting—the difficulty of finding some objects—has not been a source of embarrasment. In fact the instability of the optical axis in reflecting instruments, if the mirror is unconstrainedly supported, as it should be, renders them unsuitable for determinations of position. A little patience will enable an observer to find all necessary tests, or curious objects.

The mounting is divided into: a. The Tube; and b. The supporting frame.

a. *The Tube.*

The telescope tube is a sixteen sided prism of walnut wood, 18 inches in diameter, and 12 feet long. The staves are $\frac{3}{8}$ of an inch thick, and are hooped together with four bands of brass, capable of being tightened by screws. Inside the tube are placed two rings of iron, half an inch thick, reducing the internal diameter to about 16 inches. At opposite sides of the upper end of the tube are screwed the perforated trunnions *a*, Fig. 28 (of which only one is shown), upon which it swings. Surrounding the other end is a wire rope $b\ b'\ b''$, the ends of which go over the pulleys *c* (*c'* not shown) on friction rollers, and terminate in disks of lead *d d'*. These counterpoises are fastened on the ends of levers *e e'*, which turn below on a fixed axle *f*.

By this arrangement as the tube assumes a horizontal position and becomes, so to speak, heavier, the counterpoises do the same, while when the tube becomes perpendicular, and most of its weight falls upon the trunnions, the counterpoises are carried mostly by their axle. A continual condition of equilibrium is thus reached, the tube being easily raised or depressed to any altitude desired. It is necessary, however, to constrain the wire rope $b\ b'\ b''$, to move in the arc of the circle described by the end of the tube and ends of the levers and hence the twelve rollers or guide pulleys $g\ g'\ g''$. Over some of the same pulleys a thin wire rope *h h'* runs, but while its ends are fastened to the lower part of the tube at *b*, the central parts go twice around a roller connected with the winch *i*, near the eye-piece, thus enabling the observer to move the telescope in altitude, without taking the eye from the eye-piece.

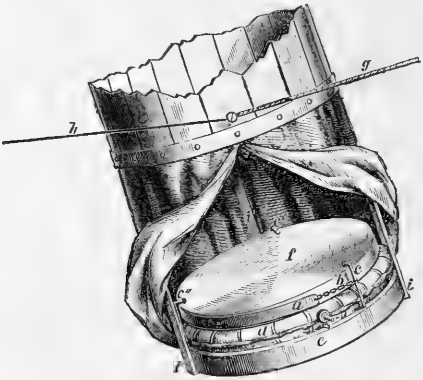


Sectional View of Observatory.

The iron wire rope required to be carefully made, so as to avoid rigidity. It contains $2\frac{1}{3}$ miles of wire, $\frac{1}{100}$ of an inch in diameter, and has 300 strands. Each single wire will support 7 pounds. It is, however, more flexible than a hempen rope of the same size, owing to its loose twisting.

At the lower end of the tube, at the distance of a foot, and crossing it at right angles, held by three bars of iron $i\, i'\, i''$, Fig. 29, is a circular table of oak e, which carries an India-rubber air sac d, and upon this the mirror f is placed. The edge support of the mirror is furnished by a semicircular band of tin-plate a, lined inside with cotton, and fastened at the ends by links of chain b, (b' not seen) to two screws $c\, c'$; g and h are the wire ropes, marked b and h in Fig. 28.

Fig. 29.



The Mirror Support.

Instead of the blanket support which Herschel found so advantageous, M. Foucault has suggested this use of an air sac. In his instrument there is a tube going up to the observer, by which he may adjust its degree of inflation. It requires that there should be three bearings $c\, c'\, c''$, in front of the mirror, against which it may press when the sac behind is inflated, otherwise the optical axis is altogether too instable, and objects cannot be found. The arrangement certainly gives beautiful definition, bringing stars to a disk when the glass just floats, without touching its front bearings. The first sac that I made was composed of two circular sheets of India-rubber cloth, joined around the edges. But this could not be used while photographing, because the image was kept in a state of continuous oscillation if there was a breeze, and even under more favorable circumstances took a long time to come to rest. It was not advisable to blow the mirror hard up against its three front bearings, in order to avoid the instability, for then every point in of an object became triple. To the eye the oscillations were not offensive, because the swaying image was sharp.

Subsequently, however, an air chair cushion was procured, and as the surface was flat instead of convex the difficulty became so much less, that the blanket support was definitely abandoned. It is necessary that the mirror should have free play in the direction of the length of the tube when this kind of support is used, and that is the reason why the tin edge hoop must terminate in links of chain.

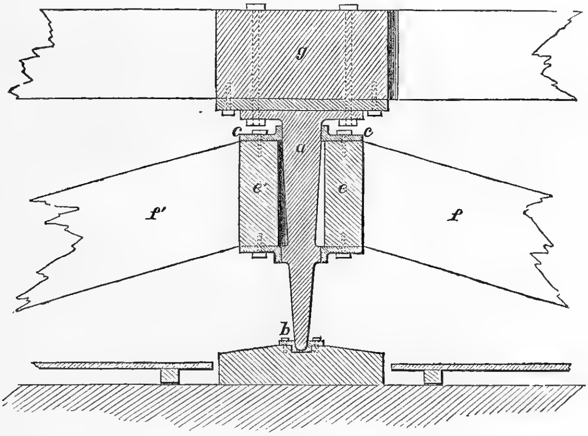
The interval, eight or ten inches, which separates the face of the mirror from the tube, is occupied by a curtain of black velvet, confined below by a drawing cord and tacked above to the tube. This permits access to the mirror to put a glass cover on it, and when shut down stops the current of air rushing up. When the instrument is not being used this curtain is left open, because the mirror and tube are in that case kept more uniform in temperature with the surrounding air.

In spite of such contrivances there is still sometimes a strong residual current in the tube. I have tried to overcome it by covering the mouth of the tube with a sheet of flat glass, but have been obliged to abandon that because the images were injured. At one time, too, when it was supposed that the current was partly from the observer's body, heated streams of air going out around the tube, the aperture in the dome was closed by a conical bag of muslin, which fitted the mouth of the telescope tightly. The only advantages resulting were mere bodily comfort and a capability of perceiving fainter objects than before, because the sky-light was shut off.

b. *The Supporting Frame.*

The frame which carries the preceding parts is of wood, and rests on a vertical axis *a*, Fig. 30, turning below in a gun-metal cup *b*, supported by a marble block resting on the solid rock. The upper end of the axis is sustained by two collars, one *c c′* above, and the other below an intermediate triangular box *e e′* from the sides of which three long beams *f f f* 12 × 3 inches diverge, gradually declining till they meet the solid rock at the limits of the excavation in which the observatory

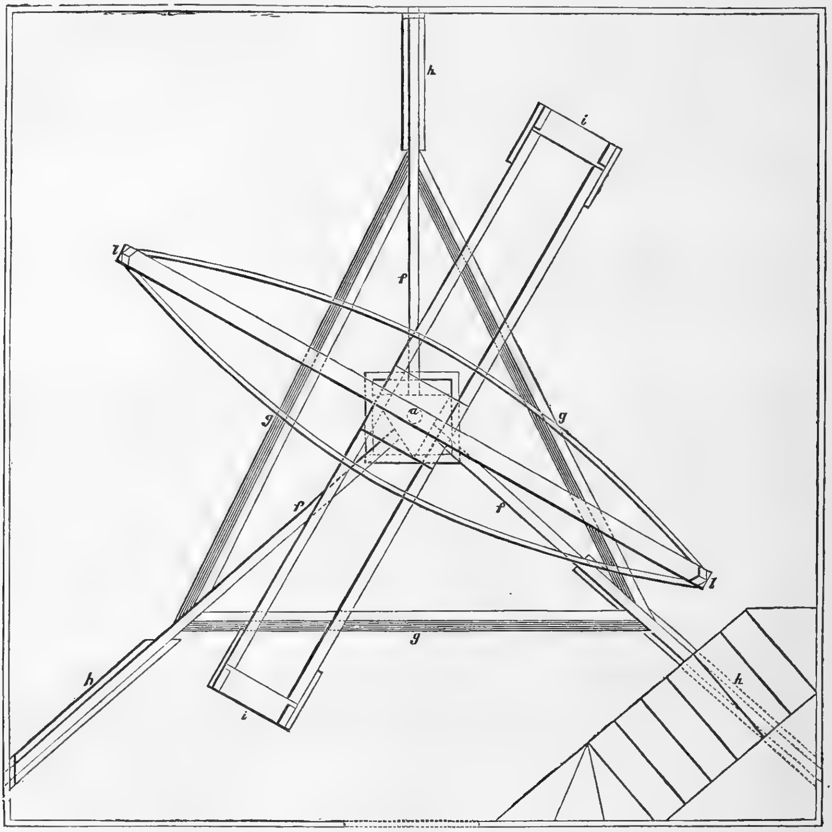
Fig. 30.



Section of Azimuth Axis.

is placed. These beams are fastened together by cross-pieces *g g g*, Fig. 31, and go through the floor in spaces *h h h*, so contrived that the floor does not touch them. At the ends they are cased with a thick leaden sheathing, to deaden vibration and prevent the access of moisture.

Fig. 31.



Plan of Observatory (lower floor).

This tripod support in connection with the sustaining of the telescope by the wire rope, gives that steadiness which is so essential in photography. Only a slight amount of force, about two pounds, is required to move the instrument in azimuth, though it weighs almost a thousand pounds.

The plan of the frame centrally carried by the axis *a* is as follows: From the corners of a parallelogram *i i* (2×13 feet) of wooden beams, eight inches thick and three inches broad, perpendiculars *n n′*, Fig. 28, rise. At the top they are connected by lighter pieces to form a parallelogram, similar to that below, and just large enough to contain the tube of the telescope. At right angles to the parallelogram below, and close upon it, a braced bar *o o′*, Fig. 28, crosses. From its extremities four slanting braces as at *p p′*, Fig. 28, go to the corners of the upper parallelogram, and combine to give it lateral support. At the top of one close pair of the perpendiculars *n′*, Fig. 28, are bronze frames carrying friction rollers upon which the trunnions move, while similarly upon the other pair *n* are two pulleys, also on friction rollers, for the wire rope coming from the counterpoises.

Movement in altitude is very easily accomplished, and with the left hand upon the winch *i*, under high powers, both altitude and azimuth motions are controlled, and the right hand left free. The whole apparatus works so well, that in ordinary observation the want of a clock movement has not been felt. Of course for photography that is essential.

§ 3. THE CLOCK MOVEMENT.

The apparatus for following celestial bodies is divided into two parts; a. The Sliding Plate-holder; and b. The Clepsydra. In addition a short description of the Sun-Camera, c, is necessary.

a. *The Sliding Plate-holder.*

Mr. De La Rue, who has done so much for celestial photography, was the first to suggest photographing the moon on a sensitive plate, carried by a frame moving in the apparent direction of her path. He never, however, applied an automatic driving mechanism, but was eventually led to use a clock which caused the whole telescope to revolve upon a polar axis, and thus compensate for the rotation of the earth, and on certain occasions for the motion of the moon herself. In this way he has produced the best results that have been obtained in Europe. Lord Rosse, too, employed a similar sliding plate-holder, but provided with clock-work to move it at an appropriate rate. I have not been able as yet to procure any precise account of either of these instruments.

The first photographic representations of the moon ever made, were taken by my father, Professor John W. Draper, and a notice of them published in his quarto work "On the Forces that Organize Plants," and also in the September number, 1840, of the London, Edinburgh, and Dublin Philosophical Magazine. He presented the specimens to the New York Lyceum of Natural History. The Secretary of that Association has sent me the following extract from their minutes:—

> "*March 23d*, 1840. Dr. Draper announced that he had succeeded in getting a representation of the moon's surface by the Daguerreotype . . . . . The time occupied was 20 minutes, and the size of the figure about 1 inch in diameter. Daguerre had attempted the same thing, but did not succeed. This is the first time that anything like a distinct representation of the moon's surface has been obtained.
>
> "ROBT. H. BROWNNE, *Secretary.*"

As my father was at that time however much occupied with experiments on the Chemical Action of Light, the Influence of Light on the Decomposition of Carbonic Acid by Plants, the Fixed Lines of the Spectrum, Spectrum Analysis, &c., the results of which are to be found scattered through the Philosophical Magazine, Silliman's Journal, and the Journal of the Franklin Institute, he never pursued this very promising subject. Some of the pictures were taken with a three inch, and some with a five inch lens, driven by a heliostat.

In 1850, Mr. Bond, taking advantage of the refractor of 15 inches aperture at Cambridge, obtained some fine pictures of the moon, and subsequently of double stars, more particularly Mizar in Ursa Major. The driving power, in this instance, was also applied to move the telescope upon a polar axis.

Besides these, several English and continental observers, Messrs. Hartnup, Phillips, Crookes, Father Secchi, and others, have worked at this branch of astronomy, and, since 1857, Mr. Lewis M. Rutherfurd, of New York, has taken many exquisite lunar photographs, which compare favorably with foreign ones.

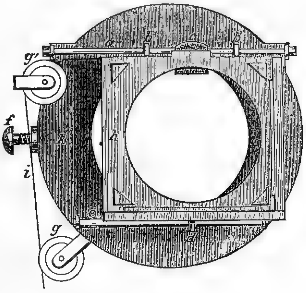
But in none of these instances has the use of the sliding plate-holder been persisted in, and its advantages brought into view. In the first place it gets rid completely of the difficulties arising from the moon's motion in declination, and in the second, instead of injuring the photograph by the tremors produced in moving the whole heavy mass of a telescope weighing a ton or more, it only necessitates the driving of an arrangement weighing scarcely an ounce.

My first trials were with a frame to contain the sensitive plate, held only at three points. Two of these were at the ends of screws to be turned by the hands, and the third was on a spring so as to maintain firm contact. This apparatus worked well in many respects, but it was found that however much care might be taken, the hands always caused some tremor in the instrument. It was evident then that the difficulty from friction which besets the movements of all such delicate machinery, and causes jerking and starts, would have to be avoided in some other way.

I next constructed a metal slide to run between two parallel strips, and ground it into position with the greatest care. This, when set in the direction of the moon's apparent path, and moved by one screw, worked better than the preceding. But it was soon perceived that although the strips fitted the frame as tightly as practicable, an adhesion of the slide took place first to one strip and then to the other, and a sort of undulatory or vermicular progression resulted. The amount of deviation from a rectilinear motion, though small, was enough to injure the photographs. At this stage of the investigation the regiment of volunteers to which I belonged was called into active service, and I spent several months in Virginia.

My brother, Mr. Daniel Draper, to whose mechanical ingenuity I have on several occasions been indebted for assistance in the manifold difficulties that have arisen while constructing this telescope, continued these experiments at intervals. He presented me on my return with a slide and sand-clock, with which some excellent photographs have been taken. He had found that unless the slide above mentioned was made ungovernably long, the same trouble continued. He then ceased catching the sliding frame *h*, Fig. 32, by two opposite sides, and made it run along a single steel rod *a*, being attached by means of two perforated plates of brass *b*, *b'*. The cord *i* going to the sand-clock, was applied so as to pull as nearly as possible in the direction of the rod. A piece of cork *c*, gave the whole steadiness, and yet softness of motion. The lower end of the frame was prevented from swinging back and forward by a steel pin *d*, which played along the glass rod *e*. All these parts were attached to a frame *k*, fitting on the eyepiece holder, and permitting the rod *a* to change from the horizontal position in which it is here drawn, to any angular one desired. The thumb-screw *f* retained it in place; *g* and *g′* are pulleys which permit the cord to change direction.

Fig. 32.

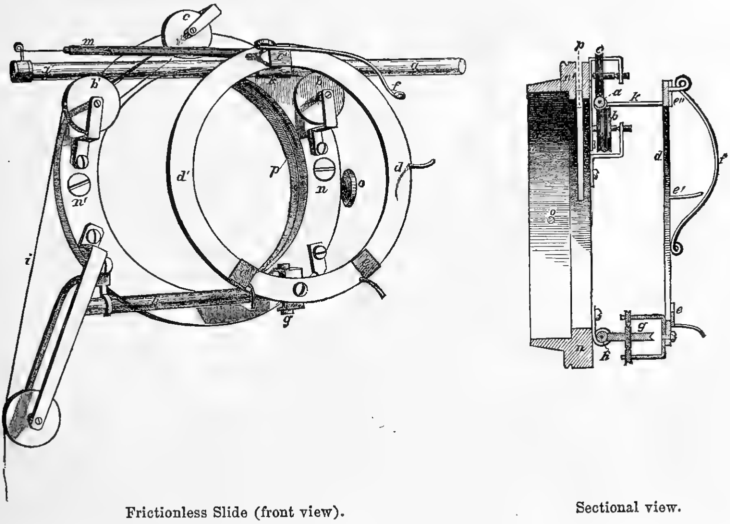


Sliding Plate-holder.

Subsequently, a better method of examining the uniformity of the rate, than by noticing the sharpness of the photograph produced, was invented. It consists in arranging a fixed microscope, magnifying about 40 times, at the back of the ground glass plate, which fits in the same slide as the sensitive plate. By watching the granulated appearance pass before the eye, as the slide is moved by the clock, the slightest variation from uniformity, any pulsatile or jerking movement is rendered visible. By the aid of this microscopic exaggeration, it was seen that occasionally, when there had been considerable changes in temperature, the steadiness of the motion varied. This was traced to the irregular slipping of *b*, *b′*.

A different arrangement was then adopted, by which a lunar crater can be kept bisected as long as is necessary, and which gives origin to no irregularities, but pursues a steady course. The principle is, not to allow a slipping friction anywhere, but to substitute rolling friction, upon wheels turning on points at the ends of their axles. The following wood-cut is half the real size of this arrangement.

Fig. 33.



Frictionless Slide (front view).

Sectional view.

A glass rod *a*, *a'*, Fig. 33, is sustained by two wheels *b*, *b'*, and kept in contact with them by a third friction roller *c*, pressed downward by a spring. This rod carries a circular frame *d*, *d'*, upon which at *e*, *e'*, *e''*, are three glass holders and platinum catches. A spring *f* holds the sensitive plate in position, by pressing against its back. The circular frame *d* is kept in one plane by a fourth friction roller *g*, which runs on a glass rod *h*, and is kept against it by the inward pressure of the overhanging frame *d*. The cord *i* is attached to the arm *k*, and pulls in the direction of the glass rod *a*. From *m* to a fixed point near *b*, a strip of elastic India-rubber is stretched, to keep the cord tight. The ring of brass *n*, *n'* carries the whole, serving as a basis for the stationary parts, and in its turn being fastened to the eyepiece holder, so as to allow the glass rod *a* to change direction, and be brought into coincidence with the apparent path of the moon. At *o* is a thumb-screw or clamp Through the ring *n*, *n'*, a groove *p* is cut, into which a piece of yellow glass may be placed, when the actinic rays are to be shut off from the plate.

Since this contrivance has been completed, all the previous difficulties have vanished. The moving of a plate can be accomplished with such precision, that when the atmosphere was steady, negatives were taken which have been enlarged to three feet in diameter.

The length of time that such a slide can be made to run is indefinite, depending in my case on the size of the diagonal flat mirror, and aperture of the eyepiece holder. I can follow the moon for nearly four minutes, but have never required to do so for more than fifty seconds. At the mouth of the instrument, where no secondary mirror is necessary, the time of running could be increased.

The setting of the frictionless slide in angular position is accomplished as follows: A ground glass plate is put into it, with the ground face toward the mirror. Upon this face a black line must have been traced, precisely parallel to the rod *a*. This may be accomplished by firmly fixing a pencil point against the ground side, and then drawing the frame *d* and glass past it, while the rest of the slide is held fast. As the moon passes across the field, the position of the apparatus must be changed, until one of the craters runs along the line from end to end. A cross line drawn perpendicular to the other, serves to adjust the rate of the clepsydra as we shall see, and when a crater is kept steadily on the intersection for twice or three times the time demanded to secure an impression, the adjustment may be regarded as complete.

It is necessary of course to expose the sensitive plate soon after, or the apparent path of the moon will have changed direction, unless indeed the slide is set to suit a future moment.

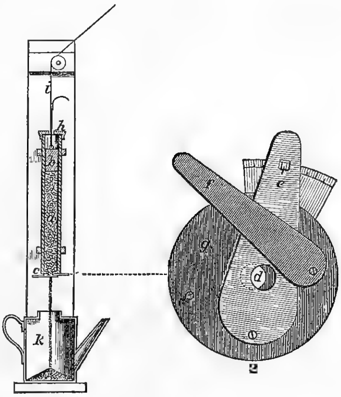
b. *The Clepsydra.*

My prime mover was a weight supported by a column of sand, which, when the sand was allowed to run out through a variable orifice below, could be made to descend with any desired velocity and yet with uniformity. In addition, by these means an unlimited power could be brought to bear, depending on the size of the weight. Previously it was proposed to use water, and compensate for the decrease in flow, as the column shortened, by a conical vessel; but it was soon perceived that as each drop of water escaped from the funnel-shaped vessel, only a corresponding weight would be brought into play. This is not the case with sand, for in this instance every grain that passes out causes the whole weight that is supported by the column to come into action. In the former instance a movement consisting of a series of periods of rest and periods of motion occurs, because power has to accumulate by floating weight lagging behind the descending water, and then suddenly overtaking it. In the latter case, on the contrary, there is a regular descent, all minor resistances in the slide being overcome by the steady application of the whole mass of the weight.

When these advantages in the flow of sand were ascertained, all the other prime movers were abandoned. Mercury-clocks, on the principle of the hydrostatic paradox, air-clocks, &c., in great variety, had been constructed.

The sand-clock consisted of a tube *a* (Fig. 34), eighteen inches long and one and a half in diameter, nearly filled with sand that had been raised to a bright red heat and sifted. Upon the top of the sand a leaden weight *b* was placed. At the bottom of the tube a peculiar stopcock, seen at (2) enlarged, regulated the flow, the amount passing depending on the size of the aperture *d*. This stopcock consisted of two thin plates, fixed at one end and free at the other. The one marked *e* is the adjusting lever, and its aperture moves past that in the plate *g*. The lever *f* serves to turn the sand off altogether, without disturbing the size of the other aperture, which, once set to the moon's rate, varies but slightly in short times. A movable cover *h*, perforated to allow the cord *i* to pass through, closed the top, while the vessel *k* retained the escaped sand, which at suitable times was returned into the tube *a*, the weight *b* being temporarily lifted out. From the clock the cord *i* communicated motion to the frictionless slide, as shown in Fig. 33. This cord should be as inelastic as possible, consistent with pliability, and well waxed.

Fig. 34.



The Sand-Clock.

One who has not investigated the matter would naturally suppose that the flow of sand in such a long tube would be much quicker when the tube was full than when nearly empty, and that certainly that result would occur when a heavy weight was put on the shifting mass. But in neither case have I been able to detect the slightest variation, for, although by shaking the tube a diminution of the space occupied by the sand may be caused, yet no increase of weight tried could accomplish the same reduction. These peculiarities seem to result from the sand arching as it were across the vessel, like shot in a narrow tube, and only yielding when the under supports are removed. In blasting, a heavy charge of gunpowder can be retained at the bottom of a hole, and made to split large masses of rock, by filling the rest of the hole with dry sand.

I believe that no prime mover is more suitable than a sand-clock for purposes where steady motion and a large amount of power are demanded. The simplicity, for instance, of a heliostat on this plan, the large size it might assume, and its small cost, would be great recommendations. In these respects its advantages over wheelwork are very apparent. The precision with which such a sand-clock goes may be appreciated when it is stated, that under a power of 300 a lunar crater can be kept bisected for many times the period required to photograph it. To secure the greatest accuracy in the rate of a sand-clock, some precautions must be taken. The tube should be free from dents, of uniform diameter, and very smooth or polished inside. Water must not be permitted to find access to the sand, and hygrometric varieties of that substance should be avoided, or their salts washed out. The sand should be burned to destroy organic matter, and so sifted as to retain grains nearly equal in size. The weight, which may be of lead, must be turned so as to go easily down the tube, and must be covered with writing paper or some other hard and smooth material, to avoid the proneness to adhesion of sand. A long bottle filled with mercury answers well as a substitute.

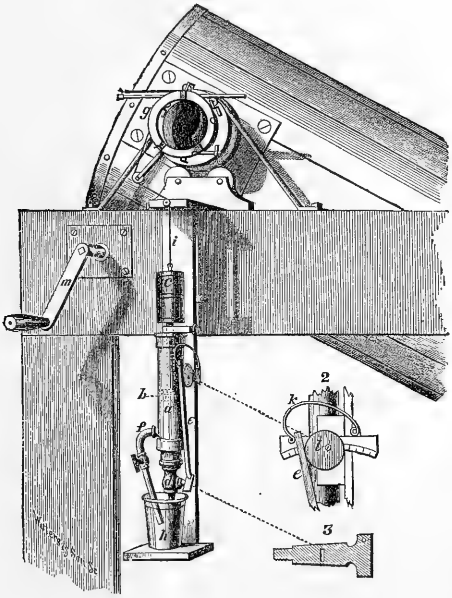
I have used in such clocks certain metallic preparations: Fine shot, on account of its equality of size, might do for a very large clock with a considerable opening below, but is unsuitable for a tube of the size stated above. There is, however, a method by which lead can be reduced to a divided condition, like fine gunpowder, when it may replace the sand. If that metal is melted with a little antimony, and while cooling is shaken in a box containing some plumbago, it breaks up at the instant of solidifying into a fine powder, which is about five times as heavy as sand. If after being sifted to select the grains of proper size, it is allowed to run through a small hole, the flow is seen to be entirely different from that of sand, looking as if a wire or solid rod were descending, and not an aggregation of particles. It is probable, therefore, that it would do better than sand for this purpose. I have not, however, given it a fair trial, because just at the time when the experiments with the sand-clock had reached this point, I determined to try a clepsydra as a prime mover.

The reason which led to this change was that it was observed on a certain occasion when the atmosphere was steady, that the photographs did not correspond in sharpness, being in fact no better than on other nights when there was a considerable flickering motion in the air. A further investigation showed that in these columns of sand there is apt to be a minute vibrating movement. At the plate-holder above this is converted into a series of arrests and advances. On some occasions, however, these slight deviations from continuous motion are entirely absent, and generally, indeed, they cannot be seen, if the parts of the image seem to vibrate on account of currents in the air. By the aid of the microscopic exaggeration described on a former page—which was subsequently put in practice—they may be observed easily, if present.

When the negative produced at the focus of the great mirror is intended to be enlarged to two feet or more in size, these movements injure it sensibly. A variety of expedients was resorted to in order to avoid them, but none proved on all occasions successful.

It is obvious that in a water-clock, where the mobility of the fluid is so much greater than that of solid grains, this difficulty would not arise. The following contrivance in which the fault of the ordinary clepsydra, in varying rate of flow as the column shortens, is avoided, was next made. With it the best results are attainable, and it seems to be practically perfect.

Fig. 35.



The Clepsydra.

It consists of a cylinder *a*, in which a piston *b* moves watertight. At the top of the piston rod is a leaden five-pound weight *c*, from which the cord *i* goes to the sliding plateholder *g*. The lower end of the cylinder terminates in a stopcock *d*, the handle of which carries a strong index rod *e*, moving on a divided arc. At *f* a tube with a stopcock is attached. Below, a vessel *h* receives the waste fluid.

In using the clepsydra the stopcock of *f* is opened, and the piston being pulled upwards, the cylinder fills with water from *h*. The stopcock is then closed, and if *d* also is shut, the weight will remain motionless. The string *i* is next connected with the slide, and the telescope turned on the moon. As soon as the slide is adjusted in angular position (page 36) the stopcock *d* is opened, until the weight *c* moves downwards, at a rate that matches the moon's apparent motion.

In order to facilitate the rating of the clepsydra, the index rod *e* is pressed by a spring *k* (2), against an excentric *l*. As the excentric is turned round, the stopcock *d* is of course opened, with great precision and delicacy. The plug of this stopcock (3) is not perforated by a round hole, but has a slit. This causes equal movements in the rod *e*, to produce equal changes in the flow. The rating requires consequently only a few moments.

The object of the side tube *f* is to avoid disturbing *d* when it becomes necessary to refill the cylinder, for when it is once opened to the right degree, it hardly requires to be touched again during a night's work. In order to arrest the downward motion of the piston at any point, a clamp screws on the piston rod, and can be brought into contact with the cylinder head, as in the figure.

That this instrument should operate in the best manner, it is essential to have the interior of the brass cylinder polished from end to end, and of uniform diameter. If any irregularity should be perceived in the rate of going, it can be cured completely by taking out the piston, impregnating its leather stuffing with fine rotten stone and oil, and then rubbing it up and down for five minutes in the cylinder, so as to restore the polish. The piston and cylinder must of course be wiped, and regreased with a mixture of beeswax and olive oil (equal parts) after such an operation. In replacing the piston, the cylinder must be first filled with water, to avoid the presence of air, which would act as a spring.

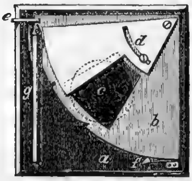
Although it may be objected that this contrivance seems to be very troublesome to use, yet that is not the case in practice. Even if it were, it so far surpasses any prime mover that I have seen, where the utmost accuracy is needed, that it would be well worth employing.

c. *The Sun Camera.*

In taking photographs of the sun with the full aperture of this telescope, no driving mechanism is necessary. On the contrary, the difficulty is rather to arrange the apparatus so that an exposure short enough may be given to the sensitive plate, and solarization of the picture avoided. It is not desirable to reduce the aperture, for then the separating power is lessened. The time required to obtain a negative is a very small fraction of a second, for the wavy appearance produced by atmospheric disturbance is not unfrequently observed sharply defined in the photograph, though these aerial motions are so rapid that they can scarcely be counted. Some kind of shutter that can admit and cut off the solar image with great quickness is therefore necessary.

In front of an ordinary camera *a*, Fig. 36, attached to the eyepiece holder of the telescope, and from which the lenses have been removed, a spring shutter is fixed. It consists of a quadrant of thin wood *b*, fastened by its right angle to one corner of the camera. Over the hole in this quadrant a plate of tin *d* can be adjusted, and held in position by a screw moving in a slot so as to reduce the hole if desired to a mere slit. It may vary from 1½ inch to less than $\frac{1}{50}$ of an inch. The quadrant is drawn downwards by an India-rubber spring *g*, 1 inch wide, ⅛ of an inch thick, and 8 inches long. This spring is stretched when in action to about 12 inches, and when released draws the slit past the aperture *c* in the camera. Two nicks in the edge of the quadrant serve with the assistance of a pin *e*, which can easily be drawn out by a lever (not shown in the cut), to confine

Fig. 36.



The Spring Shutter.

the slit either opposite to or above *c*. A catch at *f* prevents the shutter recoiling. The sensitive plate is put inside the box as usual in a plate-holder. When a photograph is taken, the spring shutter is drawn up so that the lower nick in the edge of the quadrant is entered by the pin *e*, and the inside of the camera obscured. The front slide of the plateholder is then removed in the usual manner, and the solar image being brought into proper position by the aid of the telescope finder, the trigger retaining *e* is touched, the shutter flies past *c*, and the sensitive plate may then be removed to be developed.

To avoid the very short exposure needed when a silvered mirror of 188 square inches of surface is used, I have taken many solar photographs with an unsilvered mirror, which only reflects according to Bouguer $2\frac{1}{2}$ per cent. of the light falling upon it, and should permit an exposure 37 times as long as the silvered mirror. This is the first time that a plain glass mirror has been used for such a purpose, although Sir John Herschel suggested it for observation many years ago. But eventually this application of the unsilvered mirror had to be abandoned. It has, it is true, the advantage of reducing the light and heat, but I found that the moment the glass was exposed to the Sun, it commenced to change in figure, and alter in focal length. This latter difficulty, which sometimes amounts to half an inch, renders it well nigh impossible to find the focal plane, and retain it while taking out the ground glass, and putting in the sensitive plate. If the glass were supported by a ring around the edge, and the back left more freely exposed to the air, the difficulty would be lessened but not avoided, for a glass mirror can be raised to 120° F. on a hot day by putting it in the sunshine, though only resting on a few points. Other means of reducing the light and heat, depending on the same principle, can however be used. By replacing the silvered diagonal mirror with a black glass or plain unsilvered surface, as suggested by Nasmyth, the trouble sensibly disappears.

I have in this way secured not only maculæ and their penumbræ, but also have obtained faculæ almost invisible to observation. On some occasions, too, the precipitate-like or minute flocculent appearance on the Sun's disk was perceptible.

It seems, however, that the best means of acquiring fine results with solar photography, would be to use the telescope as a Cassegranian, and produce an image so much enlarged, that the exposure would not have to be conducted with such rapidity. Magnifying the image by an eyepiece would in a general way have the same result, but in that case the photographic advantages of the reflector would be lost, and it would be no better than an achromatic.

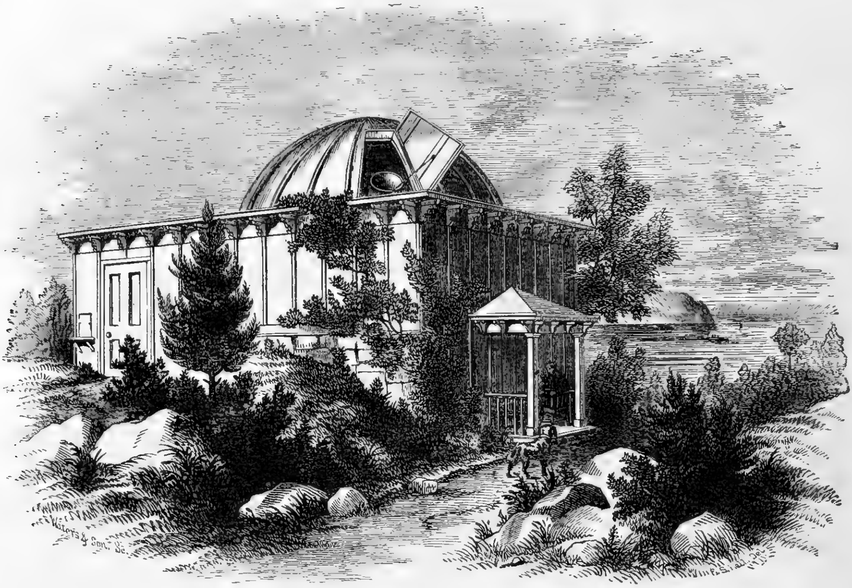
§ 4. THE OBSERVATORY.

This section is divided into *a*, The Building; *b*, The Dome; and *c*, The Observer's Chair.

a. *The Building.*

The Observatory is on the top of a hill, 225 feet above low water mark, and is in Latitude 40° 59′ 25″ north, and Longitude 73° 52′ 25″ west from Greenwich, according to the determinations of the Coast Survey. It is near the village of Hastings-upon-Hudson, and is about 20 miles north of the city of New York. The surrounding country on the banks of the North River is occupied by country seats, on the slopes and summits of ridges of low hills, and no offensive manufactories vitiate the atmosphere with smoke. Our grounds are sufficiently extensive to exclude the near passages of vehicles, and to avoid tremor and other annoyances.

Fig. 37.



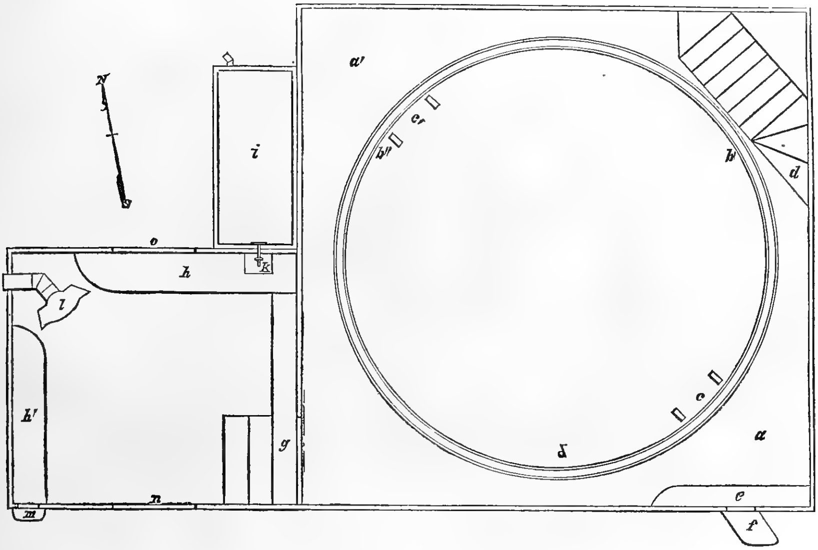
Dr. Draper's Observatory.

An uninterrupted horizon is commanded in every direction, except where trees near the dwelling house cut off a few degrees toward the southwest. The advantages of the location are very great, and often when the valleys round are filled with foggy exhalations, there is a clear sky over the Observatory, the mist flowing down like a great stream, and losing itself in the chasm through which the Hudson here passes.

The foundation and lower story of the building are excavated out of the solid granite, which appears at the edge of the hill. This arrangement was intended to keep the lower story cool, and avoid, in the case of the metal reflector, sudden changes of temperature. The eastern side of the lower story, however, projects over the brow of the hill, and is therefore freely exposed to the air, furnishing, when desired, both access and thorough ventilation through the door. The second story or superstructure is of wood, lined inside with boards like the story below. They serve to inclose in both cases a non-conducting sheet of air.

The inside dimensions of both stories taken together are 17½ feet square, and 22 feet high, to the apex of the dome. This space is unnecessarily large for the telescope, which only requires a cylinder 13 feet in diameter and 13 feet high. A general idea of the internal arrangement is gained from Fig. 28. In Fig. 38, *a a′* is the

Fig. 38.



Plan of Observatory (upper floor).

floor of the gallery, *b b′ b″* the circular aperture in which the telescope *c c′* turns. The staircase is indicated by *d*. The Enlarger, § 6, rests on the shelf *e*, the heliostat being outside at *f*. The door going into the photographic room is at *g*, *h h′* are tables, *i* the water tank, *k* the tap and sink, *l* the stove, *m* a heliostat shelf, *n* the door, *o* the window.

The building is kept ventilated by opening the door in the lower part, and the dome shutter, seen in Fig. 37, for some time before using the instrument. On a summer day the upper parts, and especially those close under the dome, become without this precaution very hot, and this occurred even before the tin roof was painted. Bright tinplate seems not to be able to reflect by any means all the heat that falls upon it, but will become so warm in July that rosin will melt on it, and insects which have lighted in a few moments dry up, and soon become pulverizable. A knowledge of these facts led to the abandonment of wooden sheathing under the tin, for without it when night comes on the accumulated heat radiates away rapidly, and ceases to cause aerial currents near the telescope.

The interior of the building is painted and wainscoted, and the roof is ornamented partly in blue and oak, and partly with panels of tulip-tree wood.

There are only two windows, and they are near the southern angles of the roof. While they admit sunshine on some occasions, they can on others be closed, and the interior be reduced to darkness. In the southeast corner a small opening *e* may allow a solar beam three inches in diameter to come in from a heliostat outside. The greatest facilities are thus presented for optical and photographical experiments, for in the latter case the whole room can be used as a camera obscura.

b. *The Dome.*

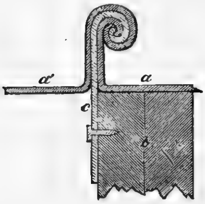
The roof of the observatory is 20 feet square. The angles are filled in solid, and a circular space 15 feet in diameter is left to be covered by the revolving dome. Although such a construction is architecturally weak and liable to lose its level, yet the great advantages of having the building below square, and the usefulness of the corners, determined its adoption, the disadvantages being overcome by a very light dome.

The dome is 16 feet in outside diameter, and rises to a height of 5 feet above its base. It is, therefore, much flatter than usual, in fact, might have been absolutely flat, with this method of mounting. It would then have been liable, however, to be crushed in by the deep winter snows.

It consists of 32 ribs, arcs of a circle, uniting at a common centre above. Each one is formed of two pieces of thin whitewood, *b*, Fig. 39, fastened side by side, with the best arrangements of the grain for strength. They are three inches wide and one inch thick at the lower end, and taper gradually to 2½ by 1.

Over these ribs tinplate is laid in triangular strips or gores, about 18 inches wide at the base, and 10 feet long. Where the adjacent triangles of tin *a a′* meet, they are not soldered, but are bent together. This allows a certain amount of contraction and expansion, and is water-proof. It strengthens the roof so much, that if the ribs below were taken away, this corrugated though thin dome would probably sustain itself. The tin is fastened to the dome ribs *b* by extra pieces *c* inserted in the joint and doubled with the other parts, while below they are nailed to the ribs. In the figure the tin is represented very much thicker than it is in reality.

Fig. 39.



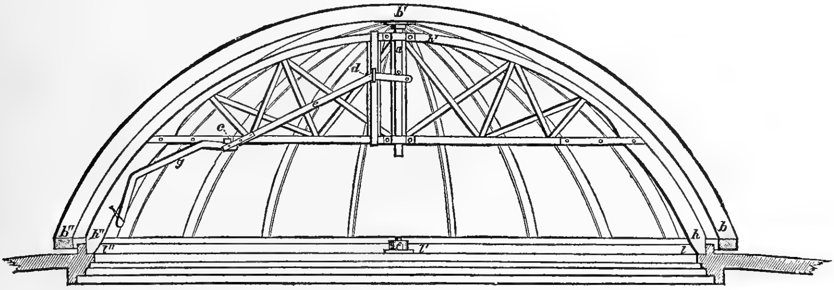
Joints in Tin of Dome.

This dome, although it has 250 square feet of surface, only weighs 250 pounds. That at the Cambridge (Massachusetts) Observatory, 29½ feet in diameter, weighs 28,000 pounds.

The slit or opening is much shorter than usual, only extending half way from the base towards the summit. It is in reality an inclined window, 2½ feet wide at the bottom, 1½ wide at the top, and 4 feet long. It is closed by a single shutter, as seen in Fig. 37, and this when opened is sustained in position by an iron rod furnished with a hinge at one end and a hook at the other.

The principal peculiarity of the dome, the means by which it is rotated, remains to be described. Usually in such structures rollers or cannon balls are placed at intervals under the edge, and by means of rack work, a motion of revolution is slowly accomplished. Here, on the contrary, the whole dome *b b′ b″* (Fig. 40) is supported on an arch *h h′ h″*, carrying an axis *a* at its centre, around which a slight direct force, a pull with a single finger, will cause movement, and by a sudden push even a quarter of an entire revolution may be accomplished. It is desirable, however, to let it rest on the edge *b b''*, when not in use. At *c* there is an iron catch on the arch, by which the lever *e*, that raises the dome, is held down. The fulcrum is at *d*. The lever is hinged near *c*, so that when by being depressed it should have come in the way of the telescope below, the lower half *g* can be pushed up, the part from *c* toward *d* still holding the dome supported.

Fig. 40.

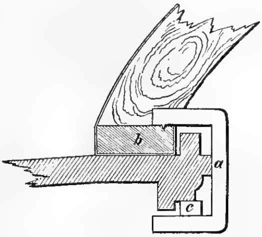


The Dome Arch.

The arch can be set across the observatory in any direction, north and south, east and west, or at any intermediate position, because the abutments where the ends rest, are formed by a ring *l l' l''*, fastened round the circular aperture, through the stationary part of the roof.

When the telescope is not in use, and the dome is let down, so that there is no longer an interval of a quarter of an inch between it and the rest of the roof, it is confined inside by four clamps and wedges. Otherwise, owing to its lightness, it would be liable to be blown away. These clamps *a*, Fig. 41, are three sides of a square, made of iron one inch square. They catch above by a point in the wooden basis-circle of the dome *b*, and below are tightened by the wedge *c*.

Fig. 41.



A Dome Clamp.

When the dome is raised it is prevented from moving laterally and sliding off by three rollers, one of which is seen at *f*, Fig. 40. These catch against its inner edge, and only allow slight play. At first it was thought necessary to have a subsidiary half arch at right angles to the other to hold it up, but that is now removed.

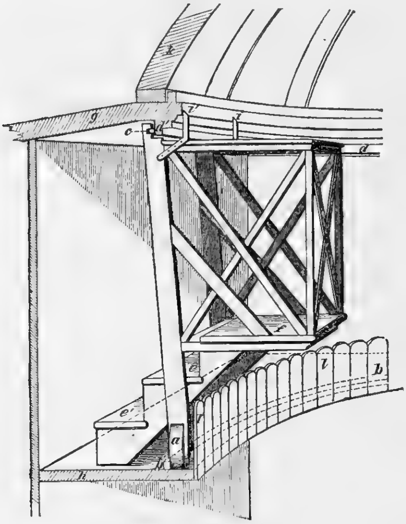
All the parts work very satisfactorily, and owing to the care taken to get the roof-circle and basis-circle flat and level, no leakage takes place at the joint, and even snow driven by high winds is unable to enter.

c. *The Observer's Chair.*

This is not a chair in the common acceptation of the word, but is rather a movable platform three feet square, capable of carrying two or more persons round the observatory, and maintaining them in an invariable position with regard to the telescope eyepiece.

Its general arrangement is better comprehended from the sketch, Fig. 42, than from a labored description. Below, it runs on a pair of wheels *a* (one only is visible) 9 inches in diameter, whose axles point to the centre of the circle upon which they run. They are prevented from shifting outwards by a wooden railroad *b*, *b′*, and inwards by the paling *l*, *l′*. Above, the chair moves on a pair of small rollers *c*, which press against a circular strip or track *d*, *d′*, nailed around the lower edge of the dome opening. Access to the platform is gained by the steps *e*, *e′*. Attached to the railing of this platform, and near it on the telescope, are two tables (not shown in the figure) for eyepieces, the sliding plateholder, &c.

Fig. 42.



The Observer's Chair.

§ 5. THE PHOTOGRAPHIC LABORATORY.

This section is divided into *a*, Description of the Apartment; and *b*, Photographic Processes.

a. *Description of the Apartment.*

The room in which the photographical operations are carried on, adjoins and connects with the observatory on the southeast, as is shown in Figs. 28 and 38. It is 9 by 10 feet inside, and is supplied with shelves and tables running nearly all the way round, which have upon them the principal chemical reagents. It is furnished, too, with an opening to admit, from a heliostat outside, a solar beam of any size, up to three inches in diameter.

The supply of water is derived from rain falling on the roof of the building, and running into a tank *i*, Fig. 38, which will contain a ton weight. The roof exposes a surface of 532 square feet, and consequently a fall of rain equal to one inch in depth, completely fills the tank. During the course of the year the fall at this place is about 32 inches, so that there is always an abundance. In order to keep the water free from contamination, the roof is painted with a ground mineral compound, which hardens to a stony consistence, and resists atmospheric influences well. The tank is lined with lead, but having been in use for many years for other purposes, is thoroughly coated inside with various salts of lead, sulphates, &c. In addition the precaution is taken of emptying the tank by a large stopcock when a rainstorm is approaching, so that any accumulation of organic matter, which can reduce nitrate of silver, may be avoided. It has not been found feasible to use the well or spring water of the vicinity.

The tank is placed close under the eaves of the building, so as to gain as much head of water as is desirable. From near its bottom a pipe terminating in a stopcock *k*, Fig. 38, passes into the Laboratory. In the northeast corner of the room, and under the tap is a sink for refuse water and solutions, and over which the negatives are developed. It is on an average about twelve feet distant from the telescope. In another corner of the room is a stove, resembling in construction an open fireplace, but sufficient nevertheless to raise the temperature to 80° F. or higher, if necessary. As a provision against heat in summer, the walls and roof are double, and a free space with numerous openings above is left for circulation of air, drawn from the foundations. The roof is of tinplate, fastened directly to the rafters, without sheathing, in order that heat may not accumulate to such an extent during the day as to constitute a source of disturbance when looking across it at night.

For containing negatives, which from being unvarnished require particular care, there is at one side of the room a case with twenty shallow drawers each to hold eighteen. They accumulate very rapidly, and were it not for frequent reselections the case would soon be filled. On some nights as many as seventeen negatives have been taken, most of which were worthy of preservation. Not less than 1500 were made in 1862 and '63.

b. *Photographic Processes.*

In photographic manipulations I have had the advantage of my father's long continued experience. He worked for many years with bromide and chloride of silver in his photo-chemical researches (Journal of the Franklin Institute, 1837), and when Daguerre's beautiful process was published, was the first to apply it to the taking of portraits (Phil. Mag., June, 1840) in 1839; the most important of all the applications of the art. Subsequently he made photographs of the interference spectrum, and ascertained the existence of great groups of lines *M*, *N*, *O*, *P*, above *H*, and totally invisible to the naked eye (Phil. Mag., May, 1843). The importance of these results, and of the study of the structure of flames containing various elementary bodies, that he made at the same time, are only now exciting the interest they deserve.

In 1850, when his work on Physiology was in preparation, and the numerous illustrations had to be produced, I learnt microscopic photography, and soon after prepared the materials for the collodion process, then recently invented by Scott Archer. We produced in 1856 many photographs under a power of 700 diameters, by the means described in the next section.

At first the usual processes for portrait photography were applied to taking the Moon. But it was soon found necessary to abandon these and adopt others. When a collodion negative has to be enlarged—and this is always the case in lunar photography, where the original picture is taken at the focus of an object glass or mirror —imperfections invisible to the naked eye assume an importance which causes the rejection of many otherwise excellent pictures. Some of these imperfections are pinholes, coarseness of granulation in the reduced silver, liability to stains and markings, spots produced by dust.

These were all avoided by washing off the free nitrate of silver from the sensitive plate, before exposing it to the light, and again submitting it to the action of water, and dipping it back into the nitrate of silver bath before developing. The quantity of nitrate of silver necessary to development when pyrogallic acid is used, is however better procured by mixing a small quantity of a standard solution of that salt with the acid.

The operation of taking a lunar negative is as follows. The glass plates $2\frac{3}{4} \times 3\frac{1}{4}$ inches are kept in nitric acid and water until wanted. They are then washed under a tap, being well rubbed with the fingers, which have of course been properly cleaned. They are wiped with a towel kept for the purpose. Next a few drops of iodized collodion are poured on each side, and spread with a piece of cotton flannel. They are then polished with a large piece of this flannel, and deposited in a close dry plate box. This system of cleaning with collodion was suggested by Major Russel, to whose skilful experiments photography is indebted for the tannin process. It certainly is most effective, the drying pyroxyline removing every injurious impurity. There is never any trouble from dirty plates.

The stock of plates for the night's work, a dozen or so, being thus prepared, one of them is taken, and by movement through the air is freed from fibres of cotton. It is then coated with filtered collodion being held near the damp sink. The coated plate, when sufficiently dry, is immersed in a 40 grain nitrate of silver bath, acidified with nitric acid until it reddens litmus paper. The exact amount of acid in the bath makes in this "Washed Plate Process" but little difference. When the iodide and bromide of silver are thoroughly formed the plate is removed, drained for a moment, and then held under the tap till all greasiness, as it is called, disappears. Both front and back receive the current in turn.

It is then exposed, being carried on a little wooden stand, Fig. 43, covered with filtering paper to the telescope, and deposited on the sliding plateholder which has been set to the direction and rate of the moon, while the plate was in the bath. The time of exposure is ascertained by counting the beats of a half-second pendulum.

The method by which exposure without causing tremor is accomplished, is as follows: A yellow glass slides through the eyepiece-holder, Fig. 33, just in front of the sensitive plate, and is put in before the plate. The yellow-colored moon is centred on the collodion film, and the clepsydra and slide are set in motion, the mass of the telescope being at rest. A pasteboard screen is put in front of the telescope, and the yellow glass taken out. After 20 seconds the instrument remaining still untouched and motionless, the screen is withdrawn, and as many seconds allowed to elapse as desirable. The screen is then replaced and the plate taken back to the photographic room.

Fig. 43.

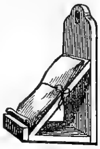
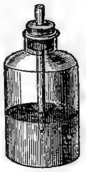


Plate Carrier.

After being again put under the tap to remove any dust or impurity, it is dipped into the nitrate bath for a few seconds. Two drachms of a solution of protosulphate of iron 20 grains, acetic acid 1 drachm, and water 1 ounce, is poured on it. As soon as the image is fairly visible this is washed off, and the development continued if necessary with a weak solution of pyrogallic acid and citro-nitrate of silver—pyrogallic and citric acids each $\frac{1}{5}$ grain, nitrate of silver $\frac{1}{10}$ grain, water 1 drachm. In order to measure these small quantities standard solutions of the substances are made, so that two drops of each contain the desired amount. They are kept in bottles, through the corks of which pipettes descend to just below the level of the liquid. This avoids all necessity of filtering, and yet no blemishes are produced by particles of floating matter.

Fig. 44.

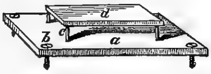


Pipette Bottle.

During the earlier part of the development, when the protosulphate of iron is on the film, an accurate judgment can be formed as to the proper length of time for the exposure in the telescope. If the image appears in 10 seconds, it will acquire an appropriate density for enlargement in 45 seconds, and will have the minimum of what is called fogging and the smallest granulations. If it takes longer to make its first appearance the exposure must be lengthened, and vice versa.

The latter part of the development, when re-development is practised, is purposely made slow, so that the gradation of tones may be varied by changing the proportion of the ingredients. As it would be tiresome and uncleanly to hold the plates in the hand, a simple stand is used to keep them level. It consists of a piece of thin wood *a*, Fig. 45, with an ordinary wood screw, as at *b*, going through each corner. Four wooden pegs, as at *c*, furnish a support for the plate *d*. By the aid of this contrivance and the washing system, I seldom get my fingers marked, and what is much more important, rarely stain a picture.

Fig. 45.



Developing Stand.

When the degree of intensity most suitable for subsequent enlargement is reached, that is, when the picture is like an overdone positive, the plate is again flooded with water, treated with cyanide of potassium or hyposulphite of soda, once more washed and set upon an angle on filtering paper to dry. It is next morning labelled, and put away unvarnished in the case.

To the remark that this process implies a great deal of extra trouble, it can only be replied that more negatives can be taken on each night than can be kept, and that, even were it not so, one good picture is worth more than any number of bad ones.

Although the above is the method at present adopted, and by which excellent results have been obtained, it may at any moment give place to some other, and is indeed being continually modified. The defects it presents are two—first, the time of exposure is too long, and second, there is a certain amount of lateral diffusion in the thickness of the film, and in consequence a degree of sharpness inferior to that of the image produced by the parabolic mirror. The shortest time in which the moon has been taken in this observatory has been one-third of a second, on the twenty-first day, but on that occasion the sky was singularly clear, and the intrinsic splendor of the light great. The full moon under the same circumstances would have required a much shorter exposure. A person, however, who has put his eye at the focus of such a silvered mirror will not be surprised at the shortness of the time needed for impressing the bromo-iodide film; the brilliancy is so great that it impairs vision, and for a long time the exposed eye fails to distinguish any moderately illuminated object. The light from 188 square inches of an almost total reflecting surface is condensed upon 2 square inches of sensitive plate.

Occasionally a condition of the sky, the reverse of that mentioned above, occurs. The moon assumes a pale yellow color, and will continue to be of that non-actinic tint for a month or six weeks. This phenomenon is not confined to special localities, but may extend over great tracts of country. In August, 1862, when our regiment was encamped in Virginia, at Harper's Ferry, the atmosphere was in this condition there, and was also similarly affected at the observatory, more than 200 miles distant. As to the cause, it was not forest or prairie fires, for none of them of sufficient magnitude and duration occurred, but was probably dust in a state of minute division. No continued rain fell for several weeks, and the clay of the Virginia roads was turned into a fine powder for a depth of many inches. The Upper Potomac river was so low that it could be crossed dry-shod. On a subsequent occasion when the same state of things occurred again, I exposed a series of plates (whose sensitiveness was not less than usual, as was proved by a standard artificial flame) to the image of the full moon in the 15½ inch reflector for 20 seconds, and yet obtained only a moderately intense picture. This was 40 times as long as common.

Upon all photographic pictures of celestial objects the influence of the atmosphere is seen, being sometimes greater and sometimes less. To obtain the best impressions, just as steady a night is necessary as for critical observations. If the image of Jupiter is allowed to pass across a sensitive plate, a streak almost as wide as the planet is left. It is easily seen not to be continuous, as it would have been were there no atmospheric disturbances, but composed of a set of partially isolated images. Besides this planet, I have also taken impressions of Venus, Mars, double stars, &c.

An attempt has been made to overcome lateral diffusion in the thickness of the film by the use of dry collodion plates, more particularly those of Major Russel and Dr. Hill Norris. These present, it is true, a fine and very thin film during exposure, but while developing are so changed by wetting in their mechanical condition that no advantage has resulted. It was while trying them, that I ascertained the great control that hot water exercises over the rapidity of development, and time of exposure, owing partly no doubt to increase of permeability in the collodion film, but also partly to the fact that chemical decompositions go on more rapidly at higher temperatures. I have attempted in vain to develop a tannin plate when it and the solutions used were at 32° F., and this though it had had a hundred times the exposure to light that was demanded when the plate was kept at 140° F. by warm water.

Protochloride of palladium, which I introduced in 1859, is frequently employed when it is desired to increase the intensity of a negative without altering its thickness. This substance will augment the opacity 16 times, without any tendency to injure the image or produce markings. It is only at present kept out of general use by the scarcity of the metal.

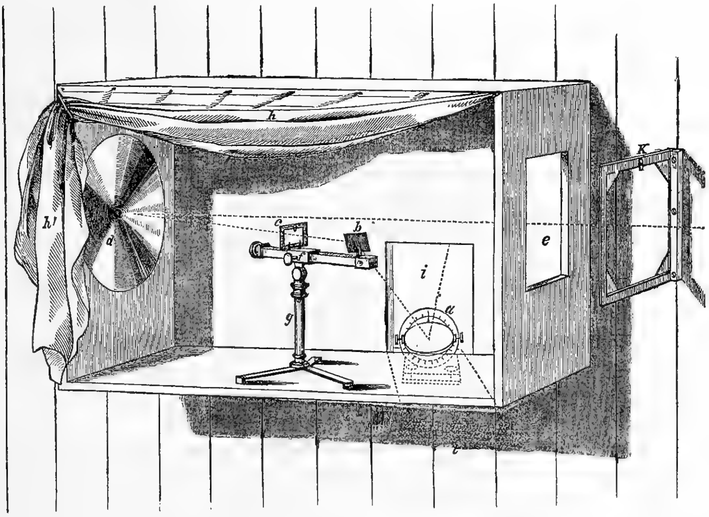
§ 6. THE PHOTOGRAPHIC ENLARGER.

Two distinct arrangements are used for enlarging, *a*, for Low Powers varying from 1 to 25; and *b*, for High Powers from 50 to 700 diameters.

a. *Low Powers.*

The essential feature in this contrivance is an entire novelty in photographic enlargement, and it is so superior to solar cameras, as they are called, that they are never used in the observatory now. It consists in employing instead of an achromatic combination of lenses, a *mirror* of appropriate curvature to magnify the original negatives or objects. The advantages are easily enumerated, perfect coincidence of visual and chemical foci, flat field, absolute sharpness of definition. If the negative is a fine one, the enlarged proofs will be as good as possible.

Fig. 46.



The Photographic Enlarger.

The mirror is of 9 inches aperture, and 11½ inches focal length. It was polished on my machine to an elliptical figure of 8 feet distance between the conjugate foci, and was intended to magnify 7 times. At first the whole mirror was allowed to officiate, the object being illuminated by diffused daylight. But it was soon apparent, that although a minute object placed in one focus was perfectly reproduced at the other, seven times as large, yet a large one was not equally well defined in all its parts.

I determined then to produce the enlarged image by passing a solar-beam $1\frac{1}{2}$ inch in diameter through the original lunar negative—placed in the focus nearest to the mirror—and allowing it to fall on a portion of the concave mirror, $1\frac{1}{2}$ inch in diameter, at one side of the vertex. Being reflected, it returns past the negative, and goes to form the magnified image at the other focus of the ellipse.

In Fig. 46, *a* is the heliostat on a stone shelf outside; *b* a silvered glass mirror, to direct the parallel rays through *c*, the negative; *d* is the elliptical mirror; *e* an aperture to be partly closed by diaphragms; *f* a rackwork movement carried by the tripod *g*; the curtain *h h′* shuts out stray light from the interior of the observatory. The aperture *i* is also diaphragmed, but is shown open to indicate the position of the heliostat, the shelf of which joins the outside of the building at *l*. The dotted line points out the course of the light, which coming from the sun falls on the heliostat mirror *a*, then on *b*, through *c* to *d*, and thence returning through *e* to the sensitive plate in the plate holder *k*.

The distance of this last can be made to vary, being either two feet or twenty-eight feet from *d*. In the latter case a magnifying power of about 25 results, the moon being made three feet in diameter. The sensitive plate is carried by a frame, which screws to the side wall of the building, and can be easily changed in position. The focussing is accomplished by the rack *f*. Where so small a part ($1\frac{1}{2}$ inch) of the surface of the mirror is used, a rigid adherence then to the true foci of this ellipse is not demanded, the mirror seeming to perform equally well whether magnifying 7 or 25 times. Theoretically it would seem to be limited to the former power.

If instead of placing a lunar photograph, which in the nature of the case is never absolutely sharp, at *c*, some natural object, as for instance a section of bone, is attached to the frame moved by *f*, then under a power of 25 times it is as well defined as in any microscope, while at the same time the amount of its surface seen at once is much larger than in such instruments, and the field is flat. If the intention were, however, to make microscopic photographs, a mirror of much shorter focal length would be desirable, one approaching more to those of Amici's microscopes.

By the aid of a concave mirror used thus obliquely, or excentrically, all the difficulties in the way of enlarging disappear, and pictures of the greatest size can be produced in perfection. I should long ago have made lunar photographs of more than 3 feet in diameter, except for the difficulties of manipulating such large surfaces.

In order to secure a constant beam of sunlight a heliostat is placed outside the observatory, at its southeast corner *f*, Fig. 38. This beam, which can be sent for an entire day in the direction of the earth's axis, is intercepted as shown at *b*, Fig. 46, and thus if needed an exposure of many hours could be given. The interior of the observatory and photographic room being only illuminated by faint yellow rays, no camera box is required to cut off stray light. The eye is by these means kept in a most sensitive condition, and the focussing can be effected with the critical accuracy that the optical arrangement allows, no correction for chromatic aberration being demanded.

I have made all the parts of this apparatus so that they can be easily separated or changed. The flat mirrors are of silvered glass, and are used with the silvered side toward the light, to avoid the double image produced when reflection from both sides of a parallel plate of glass is permitted. The large concave mirror happens to be of speculum metal, but it can be repolished if necessary by means of a four inch polisher, passed in succession over every chord of the face. A yellow film of tarnish easily accumulates on metal specula if they are not carefully kept, and decreases their photographic power seriously.

Of the making of Reverses.—In addition to the use of the Enlarger for magnifying, it is found to have important advantages in copying by contact. The picture of the image of the moon produced in the telescope is negative, that is, the lights and shades are reversed. In enlarging such a negative reversal again takes place, and a positive results. This positive cannot, however, be used to make prints on paper, because in that operation reversing of light and shade once more occurs. It is necessary then at some stage to introduce still another reversal. This may be accomplished either by printing from the original negative a positive, which may be enlarged, or else printing from the enlarged positive a negative to make the paper proofs from. In either case a collodion film, properly sensitized, is placed behind the positive or negative, and the two exposed to light.

If diffused light or lamplight is used, the two plates must be as closely in contact as possible, or the sharpness of the resulting proof is greatly less than the original. This is because the light finds its way through in many various directions. If the two plates, however, are placed in the cone of sunlight coming from the Enlarger, and at a distance of fifteen or twenty feet from it, the light passes in straight lines and only in one direction through the front picture to the sensitive plate behind. I have not been able to see under these circumstances any perceptible diminution in sharpness, though the plates had been $\frac{1}{16}$ of an inch apart. It is perfectly feasible to use wet collodion instead of dry plates, no risk of scratching by contact is incurred, and the whole operation is easily and quickly performed. The time of exposure, 5 seconds, is of convenient length, but may be increased by putting a less reflecting surface or an unsilvered glass mirror in the heliostat. A diaphragm with an aperture of half an inch if placed at *e*, Fig. 46, to shut out needless light, and avoid injuring the sharpness of the reverse by diffusion through the room. In enlarging other diaphragms are also for the same reason put in the place of this one. For a half moon for instance, a yellow paper with a half circular aperture, whose size may be found by trial in a few minutes, is pinned against *e*.

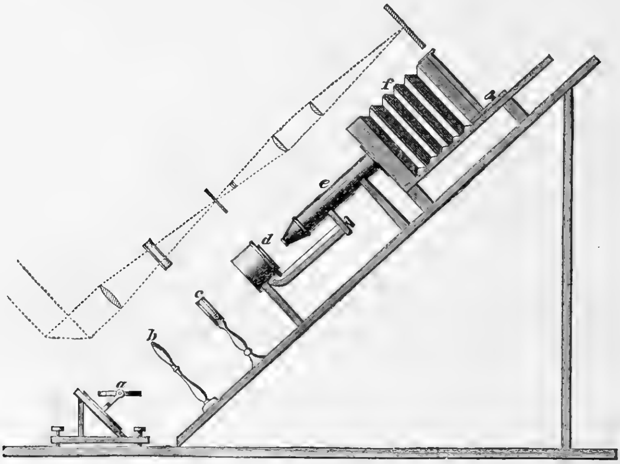
The enlarged pictures obtained by this apparatus are much better than can be obtained by any other method known at present. The effect, for instance, of a portrait, made life-size, is very striking. Some astronomers have supposed that advantages would arise from taking original lunar negatives of larger size in the telescope, that is, from enlarging the image two or three times by a suitable eyepiece or concave achromatic, before it reached the sensitive plate. But apart from the fact that a reflector would then have all the disadvantages of an achromatic, the atmospheric difficulties, which in reality constitute the great obstacle to success, would not be diminished by such means. The apparent advantage, that of not magnifying defects in the collodion, is not of much moment, for when development of the photographs is properly conducted, and thorough cleanliness practised, imperfections are not produced, and the size of the silver granules is not objectionable.

b. *High Powers.*

Although negatives of astronomical objects have not as yet been made which could stand the high powers of the arrangement about to be described, yet they bear the lower powers well, and give promise of improvement in the future.

Photography of microscopic objects as usually described, consists in passing a beam of light through the transparent object into the compound body of the microscope, and receiving it on its exit from the eyepiece upon a ground glass or sensitive plate. The difficulty which besets the instrument generally, and interferes with the production of fine results, arises from the uncertainty of ascertaining the focus or place for the sensitive plate. For if the collodion film be put where the image on ground glass seems best defined, the resulting photograph will not be sharp, because the actinic rays do not form their image there, but either farther from or nearer to the lenses, depending on the amount of the chromatic correction given by the optician. Practically by repeated trials and variation of the place of the sensitive compound, an approximation to the focus of the rays of maximum photographic intensity is reached.

Fig. 47.



Microscope for Photography.

During my father's experiments on light, and more particularly when engaged in the invention of portrait photography, he found that the ammonio-sulphate of copper, a deep blue liquid, will separate the more refrangible rays of light, the rays concerned in photography, from the rest. If a beam of sunlight be passed through such a solution, inclosed between parallel plates of glass, and then condensed upon an object on the stage of a microscope, a blue colored image will be formed on the ground glass, above the eyepiece. If the place of best definition be carefully ascertained, and a sensitive plate put in the stead of the ground glass, a sharp photograph will always result.

Besides, there is no danger of burning up the object, as there would be if the unabsorbed sunlight were condensed on it, and hence a much larger beam of light and much higher powers can be used. The best results are attained when an image of the sun produced by a short focussed lens is made to fall upon and coincide with the transparent object. In 1856 we obtained photographs of frog's blood disks, navicula angulata, and several other similar objects under a power of 700 diameters, excellently defined. Since then several hundreds of microscopic pictures have been taken.

In the figure, *a* is the heliostat, *b* a lens of three inches aperture, *c* the glass cell for the ammonio-sulphate of copper, *d* the object on the stage of the microscope *e*, *f* the camera for the ground glass or sensitive plate. Above the figure the course of the rays is shown by dotted lines.

In concluding this account of a Silvered Glass Telescope I may answer an inquiry which doubtless will be made by many of my readers, whether this kind of reflector can ever rival in size and efficiency such great metallic specula as those of Sir William Herschel, the Earl of Rosse, and Mr. Lassell? My experience in the matter, strengthened by the recent successful attempt of M. Foucault to figure such a surface more than thirty inches in diameter, assures me that not only can the four and six feet telescopes of those astronomers be equalled, but even excelled. It is merely an affair of expense and patience. I hope that the minute details I have given in this paper may lead some one to make the effort.

HASTINGS, WESTCHESTER COUNTY,
NEW YORK, 1863.

Postscript.—Since writing the above I have completed a photograph of the moon 50 inches in diameter. The original negative from which it has been made, bears this magnifying well, and the picture has a very imposing effect.

PUBLISHED BY THE SMITHSONIAN INSTITUTION,

WASHINGTON CITY,

JULY, 1864.

SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.
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PALÆONTOLOGY

OF THE

UPPER MISSOURI:

A REPORT UPON COLLECTIONS MADE PRINCIPALLY BY THE EXPEDITIONS UNDER COMMAND OF LIEUT. G. K. WARREN, U. S. TOP. ENGRS., IN 1855 AND 1856.

INVERTEBRATES.

BY

F. B. MEEK AND F. V. HAYDEN, M.D.

PART I.

ACCEPTED FOR PUBLICATION, MAY, 1864.

COMMISSION

TO WHICH THIS PAPER HAS BEEN REFERRED.

Isaac Lea.
Prof. James D. Dana.

Joseph Henry,
Secretary S. I.

COLLINS, PRINTER,
PHILADELPHIA.

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INTRODUCTION.

THE following Memoir is the first part of a work intended to contain descriptions and illustrations of the invertebrate fossil remains collected by the Exploring Expeditions under the command of Lieut. (now Maj.-Gen.) G. K. Warren, as well as by Dr. Hayden and others, in the Upper Missouri country.[1] It was originally prepared with the expectation that it would form part of Lieut. Warren's official report to the War Department, but circumstances having prevented the final completion of the latter, with the concurrence of Lieut. Warren, the Memoir was offered to the Smithsonian Institution by the authors for publication in the Smithsonian Contributions to Knowledge.

Much the larger proportion of these collections being from the Cretaceous and Tertiary rocks, which occupy almost the entire surface of the great area explored, it was at first intended to confine the work entirely to the full illustration and description of the fossils of these two epochs. The subsequent interesting discovery, however, of Jurassic and Primordial rocks, with the intermediate Carboniferous beds at the Black Hills and a few other localities, and of the Permian in Kansas, rendered it necessary that some attention should also be given to the organic remains of these older deposits. Yet as the Carboniferous beds, which are very fossiliferous, only occupy inconsiderable portions of the country to be reported upon, while a large number of the fossils occurring in them are identical with forms already published in various State and General Government Reports, and elsewhere, it has not been deemed desirable to attempt to include all the known species from the rocks of that age within the field of exploration, as this alone would require an extensive work. The plan adopted, therefore, is to give full descriptions and figures of all the known Tertiary, Cretaceous, Jurassic, and Primordial fossils of this region; together with the new, and a few otherwise interesting forms, contained in the collections from the Permian and Carboniferous rocks of Kansas and Southeastern Nebraska.[2]

The first part of this work, now presented, includes the Primordial, Carboniferous,[3] Permian, and Jurassic species, which constitute but a small proportion of

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[1] This great extent of country was formerly known under the general name of Nebraska Territory, but has been recently divided into Dakota, Nebraska, and Montana Territories.

[2] No middle or upper Silurian, or Devonian beds, have yet been identified by fossils, at any locality in the country explored, north of the South Pass.

[3] It is proper to state, for the information of those not acquainted with the geology of the western Territories, that the few carboniferous species here figured were not selected, with one or two excep-

the whole. The next part, which will be the largest, will contain the Cretaceous species, and the third the Tertiary. Along with the second or third part, an introductory chapter will be presented, giving a general sketch of the geological formations from which these fossils were collected; their geographical range, lithological characters, thickness, &c.; with remarks on their relations to formations further eastward, both in this country and Europe.

In order to make the work as useful as possible to students, descriptions of the genera and families to which these fossils belong have also been added. Under each family, all the genera, both recent and fossil, believed to be properly included, are mentioned; while the relations of the genera described are discussed, and at the head of each generic description the synonyms, with full references, are given; likewise, when known, the etymology of the name, and the typical species of each genus. The probable periods at which the several genera, as defined, were introduced, when they attained their maximum development, and at what time they seem to have died out, if not represented in our existing seas, are also stated.

The portion of the work now presented, contains a larger amount of text, in proportion to the number of species figured and described, than will be found in the succeeding parts, in consequence of the fact that descriptions of a number of genera and families are here given which it will not be necessary to repeat, the plan being to refer back to these descriptions when other species belonging to any of these groups come to be mentioned subsequently.

From the references at the head of the specific descriptions it will be seen that preliminary notices of most of the species have been published, from time to time, under the joint names of the authors, in the Proceedings of the Philadelphia Academy of Natural Sciences. Subsequently these descriptions have been almost entirely rewritten, and extended, by the senior author (Mr. Meek), who has likewise prepared the accompanying descriptions of genera and families, with the remarks on their relations, geological and geographical range, &c.

The authors avail themselves of this opportunity to acknowledge their obligations to Prof. Henry for the use of rooms, books, and other facilities at the Smithsonian Institution, during the progress of the work: also to Prof. Dana and Prof. Agassiz, for the use of a few rare works, not in the Smithsonian library.

They are also under obligations to most of the geologists and palæontologists of the country, either for information in regard to types described by them, or respecting the geological range of particular forms in their several fields of observation. In this connection they take pleasure in mentioning the names of Mr. T. A. Conrad and Mr. Wm. M. Gabb, of Philadelphia; Dr. B. F. Shumard, of St. Louis; Mr. E. Billings, of the Canadian Geological Survey; Prof. George H. Cook, State Geologist of New Jersey; Mr. A. H. Worthen, State Geologist of Illinois; and Prof. A. Winchell, State Geologist of Michigan.

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tions, as examples of the more characteristic forms found in rocks of that age here, but because they are either new to science, or have not been previously well illustrated in this country. Geologists, however, may rest assured that they all occur directly associated with all our most common western Coal Measure species.

To the several conchologists and laborers in other departments of Natural History, with whom they have more or less freely communicated, and from whom they have received occasional suggestions, they desire to express their thanks, without having it thereby understood that any of these gentlemen are responsible for conclusions finally adopted. Those to whom their acknowledgments are more especially due are, Dr. Wm. Stimpson, and Prof. Theo. Gill, of Washington, D. C.; Dr. A. A. Gould, of Boston; Dr. Isaac Lea and Mr. Geo. W. Tryon, of Philadelphia; Dr. P. P. Carpenter, of Warrington, England; Mr. W. G. Binney, of Burlington, New Jersey; Mr. J. G. Anthony, of Cincinnati; and Mr. Temple Prime and Thomas Bland, of New York.

Most of the published works on Geology, Palæontology, and Conchology have been consulted during the preparation of the work, and a list of these will be appended to one of the succeeding parts.

PALÆONTOLOGY OF THE UPPER MISSOURI.

SILURIAN AGE.

(POTSDAM OR PRIMORDIAL PERIOD.)

MOLLUSCA.

Class **BRACHIOPODA.**

Family LINGULIDÆ.

Shell subequivalve, hingeless, oblong, oval, subtrigonal, or suborbicular, covered with a corneous epidermis; texture subcorneous or testaceous; structure laminated and minutely tubular or more or less compact; interior without calcified spiral or loop-like appendages.

Animal with elongated fleshy, subspiral oral arms, situated on each side of the mouth, and fringed with numerous cirrhi; attached by a thick peduncle passing out between the beaks of the valves; mantle highly vascular, and fringed with corneous setæ.

This family includes the four known genera, *Lingula*, *Lingulepis*, *Obolus*, and *Obolella?* It was introduced at the dawn of the Silurian age, and is represented in all the succeeding formations, as well as in our existing seas.

Genus LINGULEPIS, Hall.

Synon.—*Lingula* (sp.), Owen, Report Wisconsin, Iowa and Minnesota, 1852, p. 583; Hall, Foster & Whitney's Report Lake Sup. part ii, 1851, p. 204; Meek & Hayden, Proceed. Acad. Phila. 1858, p. 49 (not *Lingula*, Brug. 1792).
Lingulepis, Hall, Sixteenth Ann. Rept. Regents' University, N. Y., 1863, p. 129.
Etym.—*Lingula*, a little tongue; λεπίς, a scale.
Type.—*Lingula pinniformis*, Owen.

Shell thin, subovate, or subtrigonal; composition and structure as in *Lingula*. Ventral or larger valve with beak more or less produced and pointed; visceral scar trilobate, with a longitudinal raised mesial line or septum—lateral divisions diverging and usually longer than the middle one. Dorsal or smaller valve with the beak less produced than that of the other; visceral scar flabelliform.

The above description is mainly as given by the author of the genus, excepting that we have described the markings seen within the valves as visceral scars instead of muscular impressions, and left out a few such characters as "inequivalve, equilateral," &c., which being common to all the genera of the family, and indeed normally characteristic of the whole class, need not be repeated in a generic description. We would remark, however, that we have had an opportunity to examine a collection of the typical species from the falls of St. Croix, recently deposited in the museum of the Smithsonian Institution, and that we have seen the peculiar visceral scar shown in the form supposed to be the smaller or dorsal valve of the same. The specimens of the other valve, we have seen, are not in a condition to show so clearly the trilobate visceral scar, though a few of them exhibit traces of its outline. From the examination of these specimens, and the published figures, we are clearly satisfied that these internal markings are the scars of the visceral sack, and not, as has been supposed, "muscular impressions." The impressions of the posterior occlusor muscles are located much as in *Lingula*, one on each side of the middle lobe of the visceral scar, in the sinus between it and the lateral lobe on each side.[1] In the other valve the minute impressions of these muscles are placed apparently within the middle lobe of the flabelliform visceral scar, much as in *Lingula*, excepting that they are closer together, and located a little farther back.

It will thus be seen that the arrangement of the muscular system in this ancient type has yet to be clearly defined, and that it is much more nearly related to the genus *Lingula* than has been supposed; though the differences in the nature of the visceral scars, and the general form of the shell, were probably coincident with differences in the structure of the animal that would place this type in a distinct genus from our modern Lingulas.

The only species yet positively known to possess the characters of this genus, is from the base of the Silurian System, though it is probable many—possibly all—of the older Palæozoic species usually referred to the genus *Lingula*, will be found to belong here. Until the interior of many species have been examined, nothing can be known in regard to the geological range of the genus. So far, however, as can be determined from external form alone, it seems to range up at least to the Medina Sandstone of N. York Upper Silurian Series—*Lingula cuneata* of Conrad, from that rock, having more nearly the outline of the typical species of this genus than that of the modern Lingulas.

Lingulepis pinniformis.

(PLATE I, Fig. 1, *a*, *b*.)

Lingula antiqua, HALL, Foster & Whitney's Report Lake Superior, 1851, p. 204, pl. xxiii, Fig. 2.—MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila., March, 1858, p. 49 (not HALL, 1847).

Lingula pinniformis, OWEN, Rept. Geol. Wisconsin, Iowa, and Minnesota, 1852, pl. i, B, Figs. 4, 6, 8, &c.

Lingulepis pinniformis, HALL, Sixteenth Report Regents' University, N. Y., 1863, p. 129, pl. vi, Figs. 14 and 16.

Shell subovate, or ovate-subtrigonal, rounded in front and angular at the beaks, moderately convex; sides converging to the beaks, with straight or concave outlines. Beaks more or less produced, that of the larger valve attenuate and acutely pointed. Surface marked by rather obscure concentric striæ, which are sometimes crossed by faint radiating lines, usually most apparent on exfoliated surfaces, and generally quite distinct near the front, on the interior surface, and on internal casts.

Length, 0.68 inch; breadth, 0.50 inch. Other individuals in the collection proportionally wider.

This shell agrees so nearly in outline with the Escanaba form figured by Prof.

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[1] On comparing the trilobate visceral scar of the larger valve in *Lingulepis*, with that of the same valve in the recent *Lingula anatina*, as figured by Mr. Davidson (Mon. Carb. Brach. Grt. Brt., p. 200), it will be seen that they are very similar, excepting in the greater prolongation of the lateral lobes in *Lingulepis*.

Hall, in Foster and Whitney's Report, as a variety of *Lingula antiqua*, that we were led to refer it to that species, not having specimens of the New York shell at hand for comparison. Nor had we at that time within reach, specimens of the Wisconsin form now made the type of the new genus *Lingulepis.* On comparison with specimens of the latter, however, we find our shells agree so nearly with them that we do not feel fully warranted in considering them distinct, though some slight differences seem to be observable. They have the same general form and attenuate beak, but appear to differ in having the beak of the larger valve more flattened towards the pointed extremity; still the species *pinniformis* seems to vary somewhat in this respect, and as our specimens are in a bad state of preservation we are not sure these differences are constant.

Should a comparison of better specimens show our shell to be distinct, it may take the name *Lingulepis dakotensis.*

Locality and position. Central part of Black Hills, Dakotah Territory. Pots dam Sandstone, at the base of the Silurian system. (No. 1026*a*, type of description and figure, Smithsonian Collection.)

Lingulepis prima.

(PLATE I, Fig. 2, *a*, *b*.)

Lingula prima (CONRAD) HALL, Palæont., New York, I, 1847, 3, Pl. i, Fig. 2, *a*, *b*.—HALL, Foster and Whitney's Rept. Lake Superior, 204, 1851, Pl. xxiii, Fig. 1.

Shell small, ovate, rather gibbous, and comparatively thick; rounded in front; sides more or less convex in outline: beaks obtuse and convex; surface marked by obscure lines of growth, and more or less distinct radiating striæ; the latter most strongly defined on exfoliated surfaces.

Length, 0.18 inch; breadth, about 0.14 inch; convexity (larger valve), 0.03 inch.

Our specimens are generally worn, or more or less exfoliated, but as near as can be determined they seem to agree with the above cited New York species. We refer them to the genus *Lingulepis*, provisionally, not having seen the muscular impressions, but believing it to be more than probable that most, if not all of the older Palæozoic species of this general form, will be found to possess the internal characters of that genus.

We would have suspected that these shorter and more oval specimens might be the dorsal valves of the *pinniformis*, were it not for their smaller size, and the fact that they are much more convex than those supposed to be the smaller valve of that species from St. Croix River.

Locality and position, same as last. (No. 1027*a*, and 1027*b*.)

Genus OBOLELLA, BILLINGS.

Synon.—*Obolella*, BILLINGS, New. sp. Sil. Foss. Nov. 1861, 7, fig. 6, *a*, *b*, *c*, *d*.
Avicula? (desquamata), HALL, Pal. New York, I, 1852, p. 292, pl. 80, f. 3.
Lingula? (desquamata), HALL, Twelfth Rept. Regents' University, N. Y., Oct. 1859, p. 66.
Etym.—Diminutive of *Obolus*, the name of a small Greek coin.
Type.—*Obolella chromatica*, BILLINGS.

"Shell ovate circular or subquadrate, convex or plano-convex. Ventral valve with a false area which is sometimes minute and usually grooved for the passage of the peduncle. Dorsal valve either with or without an area. Muscular impressions in the ventral valve, four; one pair in front of the beak near the middle or in the upper half of the shell, and the others situated one on each side near the cardinal edge. Shell calcareous. Surface concentrically striated, sometimes with thin extended lamellose edges."

"In general form these shells somewhat resemble *Obolus*, but the arrangement of the muscular impressions is different. In *Obolus* the two central scars have their smaller extremities directed downwards, converging towards each other; but in this genus the arrangement is exactly the reverse."—BILLINGS.

The six or eight known species of this genus, are small shells, and all occur near the base of the Silurian System. The group has a wide geographical range.

Obolella nana.

(PLATE I, Fig. 3, *a*, *b*, *c*, *d*.)

Obolella nana, MEEK & HAYDEN, Proceedings Acad. Nat. Sciences, Philadelphia, October, 1861, 435.—HAYDEN, Amer. Journ. Sciences, XXXIII, 1861, 2d ser. p. 73.—DANA's Geology, p. 187, Fig. 244 A.

Shell very small, subcircular or transversely suboval; moderately convex; rather thick; front broadly rounded; sides more narrowly rounded. Beak of dorsal valve short and obtuse. Ventral valve proportionally a little longer than the other, or about as wide as long, and having a slightly more prominent beak; without a distinct mesial ridge within; scar of anterior adductor muscle? located behind the middle; impressions of sliding muscles narrow; cardinal area rather narrow and flattened; groove for the passage of the peduncle shallow. Surface marked by a few small concentric grooves or impressed striæ; exfoliated specimens showing small regularly disposed radiating striæ.

Length of dorsal valve, 0.15 inch; breadth of do., 0.17 inch; convexity, 0.15 inch. Length and breadth of a ventral valve of a smaller specimen each, 0.14 inch.

This species is so closely allied to *Obolella chromatica* of Billings, the type of the genus ("New Species, Lower Sil. Foss." p. 7), that we were inclined to regard it as specifically identical, until we had an opportunity to compare it with specimens of Mr. Billings' species sent to us by him. On comparing it with these, we find it is more convex, and proportionally broader, while its concentric markings are stronger. The substance of its shell differs in showing radiating striæ on the inner laminæ of exfoliated specimens.

Locality and position, same as last. (No. 1025.)

CLASS **GASTEROPODA.**

SUB-CLASS PTEROPODA.

Order **Thecosmata.**

FAMILY CAVOLINIDÆ.

Shell non-spiral, symmetrical, more or less elongate-conical, or subglobose, curved or straight; the subglobose, and a few of the more elongate forms, provided with lateral fissures for the passage of the mantle.

Animal with two united wing-like fins, but without a foot; abdomen large; gills in pairs on the ventral side within the mantle cavity, transversely plaited and ciliated. Internal superior organs of generation on the right side. Lingual teeth 1, 1, 1 (in *Cavolina*), claw-shaped.

This family includes the following genera represented in our existing seas, viz: *Cavolina*, *Pleuropus*, *Clio*, *Balantium*, *Styliola* and *Cuvieria*. The extinct genera most probably belonging here, are *Theca*, *Salterella*, *Vaginella* and *Pterotheca?* The fossil shells *Conularia* and *Coleoprion*, are also generally referred to this family, but if there is no mistake about the existence of septa and a siphuncle in the former genus (see *Conularia trentonensis*, Pal. N. Y. Vol. I, p. 221, f. 4), it would be excluded, not only from this family, but probably from the subclass *Pteropoda*.

Genus THECA, Sowerby.

Synon.—*Theca*, J. de C. Sowerby, MSS., in Morris' Memoir, Strezelscki's N. S. Wales, 1845, p. 289.
Pugiunculus, Barrande, Neues Jahrb. für Min. 1847, p. 354.
Etymol.—ϑήκη, a sheath, case or covering.
Type.—*Theca lanceolata*, Morris.

Shell thin, more or less elongate-conical, nearly or quite straight; aperture and section trigonal or subtrigonal; surface smooth or striated. (Animal unknown.)

According to Prof. Barrande (who had not seen the description of the genus *Theca* at the time he proposed the name *Pugiunculus*), the aperture of these little shells was closed by a triangular shelly operculum. This would seem to be a rather anomalous character in the family to which this group appears to belong.

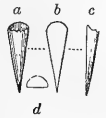
The genus *Theca* commenced its existence amongst the earliest forms of life during the primordial period, and its remains are found in various parts of the Silurian system, both upper and lower; though it probably attained its greatest development during the deposition of the Lower Silurian rocks. It is also known to range up into the Devonian, two species having been described by Sandberger from deposits of that age in the Rheinish Provinces. As one species—*T. aculeata*, Hall—has been discovered in beds in this country holding a position near the dividing line between Devonian and Carboniferous rocks, it is probable the genus did not become entirely extinct until some time after the close of the Carboniferous epoch.

Theca gregaria.

Theca (*Pugiunculus*) *gregaria*, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila., December, 1861, p. 436.—Dana's Geology, p. 187, Fig. 244 B.

Shell small, straight, acutely conical; dorsal side compressed or nearly flat; ventral side rounded; lateral margins obtusely angular, and converging regularly at an angle of about 18° to the pointed lower extremity; aperture and transverse section nearly semicircular, or forming rather more than half a circle; lip on the flat or dorsal side somewhat produced, and rounded in outline; surface of casts nearly or quite smooth.

Length, 0.45 inch; breadth, 0.15 inch; convexity, 0.10 inch at the aperture.



Theca gregaria.

a. Ventral side. *b.* Dorsal side. *c.* Side view. *d.* Transverse section.

These delicate little shells must have existed in great numbers, since on a single flat piece of sandstone, not more than six by eight inches across, we have counted near two hundred individuals, and yet they occur in all parts of the mass, so that every new surface exposed in splitting it, is seen to be covered with them. They are not crushed or distorted in the slightest degree, and are all casts, the shell itself being in no instance preserved.

The species is allied to *Theca? triangularis*, Hall (Palæont. N. Y. Vol. I, p. 313, Pl. lxxxvii, Fig. 1 *a*, *b*, *c*, *d*), but never attained near so large a size, and is more rounded on the ventral side. It is probably more nearly related to *T. primordialis*, Hall (An. Rept. Geol. Survey Wisconsin, 1861? p. 80), but never attains more than about half the linear dimensions of that species, and we have seen no traces of the arching undulations on its flat side, mentioned in the description of *T. primordialis*, though some of the impressions in the matrix show very faint indications of fine arching transverse striæ on this side. In size and form it agrees quite closely with *Salterella obtusa* of Billings (New. Sp. Low. Sil. Foss., p. 18, Montreal), but it seems to be a thinner shell, and shows no evidences of being composed of successive layers, nor is it provided with the sharp annulations seen in the type of that genus.

Locality and position. Near the head of Powder River, in Big Horn Mountain, Idaho Territory. From the Potsdam or Primordial Sandstone. (No. 1181.)

ARTICULATA.

CLASS **CRUSTACEA.**

ORDER? **Trilobita.**

FAMILY PARADOXIDÆ.

Head well developed, sometimes very large; facial sutures generally subparallel, especially the anterior portion; ribs each provided with a longitudinal furrow. Thorax large, consisting of from twelve to twenty segments. Pygidium very small, and always with few segments.

This family includes the genera *Paradoxides*, *Olenus*, *Olenellus*, *Peltura*, *Sao*, *Hydrocephalus*, *Triarthrus*, *Agraulos*, *Ellipsocephalus*, *Conocoryphe*,[1] and probably *Ptychaspis*, *Chariocephalus*, *Crepicephalus* and *Menocephalus*. It embraces a considerable number of species, some of which attain a very large size. They are generally remarkable for the great development of the thorax, compared with the small size of the pygidium. The whole family, with the exception of *Triarthrus*, seems to be mainly, if not entirely, confined to the *Primordial* or oldest group of fossiliferous rocks.

Genus AGRAULOS, CORDA.

Synon.—*Arion*, BARRANDE, Note Prélim. 1846, 12 (not Ferussac, 1819).
Herse, CORDA, Prodr. 1847 (not Oken, 1815, nor Lesson, 1837).
Agraulos, CORDA, ib. 1847.
Arionides (BARRANDE, MSS.), BRONN, Index Pal., 1848, 103.
Arionellus, BARRANDE, Syst. Sil. Boh. 1852.
Crepicephalus? (part), OWEN, Report Geol. Survey, Wisconsin, Iowa and Minnesota, 1852, p. 576.
Etymol.—Αγραυλος, daughter of the first King of Athens.
Type.—*Arion ceticephalus*, BARRANDE.

Entire animal more or less elongate-ovate, distinctly trilobate. Head forming more than a semicircle, nearly straight behind; glabella conoid-subovate, provided, in young examples, with three or four lateral furrows, which are usually nearly or quite obsolete in the adult, margined in front by a more or less developed border connecting with the cheeks on each side. Facial sutures widely separated, extending and converging forward from the eyes so as to intersect the anterior margin within a point where a line would strike it if drawn through each eye,

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[1] *Conocoryphe*, Corda, 1847 = *Conocephalus*, Zenker, 1833 (not Thunberg, 1812) = *Conocephalites*, Barrande, 1852.

parallel to the longer axis of the body; behind the eyes they diverge and extend backwards, so as to cut the straight posterior margin somewhat within the lateral angles. Cheeks small and narrow; eyes small. Hypostoma oval, truncated anteriorly. Segments of body in the adult of the typical species, sixteen; in the pygidium three.

As stated by Barrande, this genus presents several points of analogy to *Paradoxides*, particularly in the arrangement of its facial sutures, and the great number of its thoracic segments, as well as in the small size of its pygidium. In Europe it is only known to have been represented by the single typical species, which is confined to the primordial zone. Several species have been described from rocks of the same age in America, and the genus is not certainly known to have existed after the close of the Primordial epoch.

We would with pleasure adopt the name *Arionellus*, proposed for this genus by Prof. Barrande, in his splendid work on the Trilobites of Bohemia, if we could do so consistently with the just and inflexible law of priority, which we have endeavored to obey in all cases. The fact that Corda's first name, *Herse*, was applied to a young individual, would not, we should think, be a sufficient reason for setting it aside, especially as no doubt can be entertained of its generic, and even specific identity with the type of *Arionellus*. It cannot stand, however, for the reason that it had been used by Oken, in 1815, for a genus of *Lepidoptera*, and by Lesson for a genus of Birds in 1837. The next name, then, that we are compelled to consider, is *Agraulos*, which Prof. Barrande thinks should be rejected, in consequence of its similarity to *Agraulis*, used by Boisduval, in 1836, for a genus of *Lepidoptera*. These names, however, seem to us to be sufficiently distinct to prevent confusion; certainly they are as much so as many others retained in various departments of natural history—such, for instance, as *Trigonia* and *Trigona*, in Conchology, *Cyprina* and *Cyprinus*, in Conchology and Ichthyology, and *Pica* and *Picus*, in Ornithology.

We should also feel constrained, on the same principle, to adopt Corda's first name *Conocoryphe*, instead of *Conocephalus* or *Conocephalites*. The reasons for so doing will be better understood by the following statement of the synonymy of this genus. In the first place Zenker named it *Conocephalus*, in 1833. Finding this name had been used, however, in 1812, for a genus of *Orthoptera*, by Thunberg, he changed it in the explanations of his figures in the same work, to *Trigonocephalus*, which had also been previously used by Oppel for a genus of Reptiles, in 1811. In 1847, Corda applied the three generic names, *Conocoryphe*, *Ptychoparia* and *Ctenocephalus* to three species of this same genus of *Trilobites*. In 1852, Prof. Barrande, seeing that none of the older names could be adopted for this group, also rejected Corda's names, on the ground that he had, without sufficient reason, divided the genus, and that as no one of his names was applied to the whole group, he was opposed to retaining either of them, and consequently proposed the new name *Conocephalites*. The law of priority, however, requires us to adopt the first unoccupied name in this and in all other cases where no doubt can be entertained in regard to the generic identity of its type with the types of the subsequently proposed genera. The other names applied by Corda fall into the list of synonyms, just as if they had been proposed by any other author at any subsequent time.

Agraulos Oweni.

Arionellus (Crepicephalus) Oweni, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila., December, 1861, p. 436.
Arionellus? Oweni, Meek & Hayden, Am. Jour. Sci. Sec. Ser. XXXIII, 74, January, 1862.

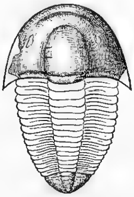
Head semi-circular, or nearly semielliptic in outline, its length equalling about two-thirds its breadth, rather distinctly convex; posterior margin more or less concave in outline, and provided with a deep, rounded marginal groove along each lateral slope. Glabella oblong-subovate, rather gibbous, elevated above the cheeks and tapering towards the rounded front with slightly convex lateral margins; greatest convexity near the middle and behind; separated from the cheeks, on each side and in front, by a distinct furrow; neck furrow passing entirely across, but slightly deeper on each side than at the middle; lateral grooves three, very short, obscure, or (in casts) nearly obsolete, and but slightly oblique. Cervical segment a little convex at its posterior outline, less elevated than the glabella. Anterior slope in advance of the glabella less than half as wide as the length of the latter, and provided with a distinct, rounded transverse furrow, which passes around slightly in front of the middle of the space parallel to the anterior and antero-lateral margins. Cheeks convex, and sloping towards the lateral and antero-lateral borders. (Surface and facial sutures unknown.)

Length of cephalic shield, measuring from the posterior side of the neck segment to the front margin, 0.57 inch; greatest breadth, measuring across at the posterior extremities of the cheeks, 0.87 inch; height, 0.31 inch. Length of glabella, including the neck segment, 0.40 inch; breadth of glabella, 0.35 inch.

A

Profile view of head.

B



Agraulos Oweni.

C

Head of a young individual.

A. Side view of a cephalic shield of *Agraulos Oweni*, the position of the eyes (which have not been distinctly seen) indicated by a dotted line.

B. Another view of the same, and of a small pygidium supposed to belong to the same species, with the body restored in outline. In this cut the marginal furrow passing around the front of the head is made to terminate rather too abruptly on each side; while the lateral furrows of the glabella are indicated too distinctly. In the specimens these furrows are very obscure, and it is difficult to see whether there were only two, or more on each side.

C. Head of a young individual, same species.

The only specimens of this species yet obtained are casts, which show no traces of the sutures, and retain no remans of surface granulations, striæ, or other markings, if there ever were any. Nor are they in a condition to show whether or not the postero-lateral extremities of the buckler are pointed, though they probably are. At a point nearly opposite the middle of the glabella, there is on each cheek, less than half way down the slope from the furrow between the fixed cheeks and the glabella, the remains of a small eye, though the specimen being unfortunately a little defective here on both sides, the exact form of these prominences cannot be clearly made out.

In the same slab containing the cephalic shield above described, we observe a pygidium which probably belongs to the same species. It is sub-semicircular in form, moderately convex, and rather distinctly, as well as nearly equally trilobate.

Its middle lobe is more prominent than the lateral, and shows three segments; the lateral lobes appear to have only two segments.

Compared with Prof. Barrande's beautiful figures of the variable typical species, *A. ceticephalus*, of its own size, the head of our species is more regularly rounded in front, and differs in having a distinct anterior marginal furrow, while its glabella is proportionally longer. A specimen of a much smaller individual in the same matrix, shows this species to have been also much less variable in the characters just mentioned, at different periods of its growth, than *A. ceticephalus.* Again, if the pygidium mentioned above belongs to the species under consideration, it was larger in proportion to the largest head we have seen, than in the European species.

Dr. Shumard and Mr. Billings, to whom we sent sketches of our species, regard it as being clearly distinct from any of the forms described by either of them from the Primordial rocks of Texas and Canada.

As the specimens of this *Trilobite* came in after our plates were made up, we could not well introduce figures of it there, but the annexed wood-cuts will give a tolerably good idea of its general appearance.

Locality and position. Near the head of Powder River, in the Big Horn Mountains, Dakota Territory. From the Primordial or Potsdam Sandstone Group. No. 1180, collection of the Smithsonian Institution. (Type 1180*a.*) Discovered by the Exploring Expedition under the command of Captain William F. Raynolds, U. S. Topographical Engineers.

Agraulos? ———— ?

(Plate I, Fig. 4.)

Comp. *Crepicephalus*, Owen, Report Geol. Wisconsin, Iowa, and Minnesota, 1852, Pl. I. A. Fig. 18.

The specimen of this species we have figured is an internal cast of a part of a cephalic shield, in a coarse brown sandstone. It is not in a condition to show any traces of the facial sutures, or even the form of the entire glabella, nor the position of the eyes, if they exist. Hence we cannot determine with much confidence to what genus it belongs, nor can we give any characters by which the species can be identified. As near as can be determined, it seems to be similar to some of the forms figured by Dr. Owen under the name *Crepicephalus.* It also resembles the foregoing species from Big Horn Mountain, and may possibly be the same. Still, as it presents some slight differences, it may prove to belong to another species. Although a mere fragment, we have thought it should be figured, since, as far as its affinities can be made out, it corroborates the evidence of the other fossils in regard to the age of the formation.

Locality and position. Central part of the Black Hills, Dakota Territory. Potsdam or Primordial Sandstone. No. 1024.

CARBONIFEROUS AGE.

(CARBONIFEROUS PERIOD.)

PROTOZOA.

CLASS **RHIZOPODA.**

ORDER **Foraminifera.**

FAMILY CAMERINIDÆ.

Shell comparatively large and dense, discoid, lenticular, fusiform, cylindrical, oval, or subglobose in outline; symmetrically involute, or rarely somewhat obliquely spiral. Last volution generally embracing all the others, so as to present, in the typical genera, the form of an *Ammonite* or *Nautilus.* Septa nearly always double, each chamber having its own walls, which, without exception, differ from the rest of the shell in being destitute of the ordinary tubular structure, so that the chambers are only connected by the principal aperture, and a few large "orbuline" pores. Canal system radiating between the double walls of the septa, generally well developed and connected with the "intermediate skeleton," secreted apparently for the consolidation of the entire structure. Aperture in the typical forms a narrow fissure placed symmetrically between the outer wall of the penultimate whorl, and the inner side of the last or outer series of chambers; sometimes partly closed by a shelly secretion so as to leave only a series of pore-like openings; in *Amphistegina* placed on the under side of the spiral plane.

In Dr. Carpenter's beautiful and elaborate Memoir on the *Foraminifera*,[1] published by the Ray Society, in 1862, the genera included in this family (there called *Nummulinida*) are the following,—in part, however, under other generic names, viz.: *Camerina*, =(*Nummulites*, Lamk.) *Amphistegina*, *Operculina*, *Elphidium*, =(*Polystomella*, Lamk.) *Heterostegina*, *Cycloclypeus*, *Orbitoides* and *Fusulina.* It includes the largest and most highly developed of the *Foraminifera*, as well as those possessing the most densely constructed shells. The living examples are mainly confined to the tropical and temperate seas, the larger types occurring in the tropics.

In regard to some of the names here adopted, a word of explanation may not be out of place. First it will be observed we use Bruguiere's name *Camerina*

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[1] To which we are mainly indebted for the characters given in the above description.

instead of *Nummulites*, Lamarck, or *Nummulina*, D'Orbigny; and as this is usually considered the typical genus of the family, we have adopted the family name *Camerinidæ*, instead of *Nautiloidæ*, or *Nummulinidæ*. Our reason for restoring Bruguiere's name, is, that it has priority over all the other regularly proposed genera. It was also adopted by Cuvier, in 1798, as well as by Lamarck himself in 1799,[1] and of course previous to the publication of *Nummulites* and *Nummulina*. This will be better understood by the following glance at the history of the genus:—

Previous to the introduction of the binomial nomenclature by Linnæus, these fossils were known to the early writers by such specific phrases as "*Helicites niger foliolis candidus*," "*Pierre lenticulaire*," "*Nummi lapidi*," "*Pierres numismalis*," &c. In 1792, however, Bruguiere proposed for them the generic name *Camerina* (Encyc. Meth. I, 396), giving at the same time a tolerably good description and history of the genus, occupying three and a half of the quarto pages of the Encyclopedia, followed by descriptions of the four species—*Camerina lævigata*, *C. striata*, *C. tuberculata*, and *C. nummularia*—all of which have been recognized by the later writers as belonging to the genus subsequently named *Nummulites*, by Lamarck, and still later, *Nummulina*, by D'Orbigny. It was in his Syst. An., published in 1801, page 101, that Lamarck first proposed the name *Nummulites*, adding little or nothing to what Bruguiere had published. In 1804 (An. Mus. V, 237), he ranged Bruguiere's species under the new generic name *Nummulites*, with very nearly the same descriptions, and references to figures and descriptions of previous authors given by Bruguiere, as he did again in 1826 (An. sans Vert., VIII, 627). In 1825, D'Orbigny, supposing the genus had living representatives, gave a third name, *Nummulina*. At various times other names were proposed for this group by other authors, but as none of them antedate Bruguiere's, and they have all been dropped out of use, they have no bearing on the question of priority, and need not be cited here.

Now we cannot recognize any right or authority for the changes made by Lamarck and D'Orbigny. Surely it cannot be urged that Bruguiere's erroneous opinion in regard to the affinities of the *Foraminifera* is a reason for setting aside his name, when Lamarck and D'Orbigny also classed them with the *Mollusca*. But even if they had discovered the true affinities of the genus, or of the order to which it belongs, this would not have given them the right to change a regularly established generic name; for if we admit such a rule, there would be no end to changes, since natural history is constantly advancing, and improvements in the classification of animals and plants are continually being made, and may be expected for a long time to come, as the affinities of the various groups are better understood. Such a rule, for instance, would have given Dujardin the right to change the names of all the genera of the entire order, when he in 1825 discovered that the *Foraminifera* are not *Cephalopoda*, nor even *Mollusks* at all, but *Protozoa*.

Nor can we admit D'Orbigny's right to change Lamarck's name *Nummulites* (had it been well founded) to *Nummulina*, if he had found a living species of the genus: since it has many fossil species, and it would be an absurdity to designate the living species of a genus by one generic name, and the fossil species by another, while the name most applicable to the fossil species has priority. Does any Conchologist, for instance, think Swainson's name *Volutilithes* should be changed

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[1] See Prodr. p. 80, where his only cited example is *C. lævigata*, Brug.

because a living species of that group was found at the Cape of Good Hope? Or, if a naturalist should dredge up from the bottom of some unexplored sea, a living Ammonite, would Palæontologists admit his right to change the name of the genus?

The other instance where we have restored an older name, is in adopting *Elphidium*, Montfort, instead of *Polystomella*, Lamarck, Montfort's name having been published in 1808, in his Conchyl. Syst., Vol. I, pp. 14–15. It is true, not very much can be said for his figure or description, but as he refers to the figures and description of Von Fitchell and Von Moll, so that later authorities do not hesitate to identify the type of his genus with a species of *Polystomella*, Lamarck, which name was not published until 1822, we feel bound to adopt his name. The fact that he gave some five or six other generic names to other species and varieties of the same genus on subsequent pages of his work, does not alter the case, for it matters not how many names an author may give a genus, we are bound to adopt his first name, if not pre-occupied, and his type can be identified, and does not belong to a previously described genus; the subsequent names of course falling into the list of synonyms.

Genus FUSULINA, Fischer.

Synon.—*Fusulina*, Fischer, Oryct. du Gouv. de Moscou, 1837, p. 126.—D'Orbigny, in Murchison, Verneuil & Keyserling's Geol. Russ. II (part iii, Pal.), 1845, p. 15.—Conr., Element. de Geol. Strat., II, 1852, 169.
Borelis (sp.); Ehrenberg, Berlin Monatsb. 1842, 274 (not Montfort, 1808).
Etym.—*Fusus*, a spindle.
Type.—*Fusulina cylindrica*, Fischer.

Shell regular, equilateral; fusiform, cylindrical or subglobose, according to its greater or less elongation in the direction of the axis, sometimes constricted around the middle; symmetrically involute so that each turn envelops all the preceding at all stages of growth. Surface with nearly parallel, subequidistant furrows coincident with the septa within, and running in the direction of the axis. Aperture a narrow slit confined to the central region. Foramina passing through the external walls of the chambers, of moderate size. Septa comparatively narrow in the middle, and gradually widening towards the extremities; apparently composed each of a single lamina; regularly undulated laterally, so as to partly subdivide each intervening chamber on each side of the broad mesial avenue (connecting the different chambers) into a series of small alternately arranged cells connected together by narrow galleries. Internal canal system, and "intermediate skeleton" apparently wanting.

The shells of this genus present the various modifications of form, and much the general appearance of the genus *Alveolina*, from which, however, they can be readily distinguished by their aperture consisting of a single mesial slit, instead of a single or multiple series of round or oval openings extending along the entire length of the shell. They also differ entirely in their internal structure, the different chambers in *Fusulina* being connected with each other by the single broad mesial slit corresponding to the aperture in the last or outer septum, and not subdivided by revolving septa; while in *Alveolina* there is another system of subordinate septa crossing the longitudinal series at right angles, and thus forming a complex system of chamberlets connected by openings passing through the principal septa, and corresponding to the numerous apertures in the last or outer septum. The surface in *Alveolina* is also marked in addition to the longitudinal furrows, by another series of smaller revolving linear depressions, coincident with the series of secondary septa. We observe Dr. Carpenter speaks with some doubt in regard to the foramina in the walls of the shells of *Fusulina*, though he thought he had seen indications of them. On making a transverse section of one of our Kansas specimens, we were enabled to see these foramina distinctly, under a high magnifying power, by transmitted light. Fig. 6, *c*, Pl. I, illustrates their appearance. We saw no satisfactory evidences of an intermediate canal system, though some of the septa seemed to exhibit slight indications of being double.

So far as known, the genus *Fusulina* is mainly, if not entirely, peculiar to the Carboniferous System.[1] In the Old World, it seems also to occur only in the Subcarboniferous Series, particularly in Russia. In this country, however, at any rate east of the Rocky Mountains, it has only been found in our Coal Measures. It is represented by one or more species, in great numbers, in the Coal Measures of some of the Western States, particularly in southeastern Nebraska, western Iowa, eastern Kansas, and portions of Missouri, Arkansas, Texas, Illinois, and, according to Mr. Verneuil (Am. Jour. Sci. (2) II, 1846, p. 293), in Ohio.

A species (*F. hyperborea*, Salter) was discovered in carboniferous rocks as high north as 76° 30′, at Depot Point, Albert's Land.

Fusulina cylindrica

(Plate I, Fig. 6, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*.)

Fusulina cylindrica, Fischer, Oryct. du Gouv. de Moscou, 1837, 126, pl. xviii, fig. 1–5.
Fusulina depressa, Fischer, ib., pl. xiii, fig. 6–11.
Fusulina cylindrica, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. December, 1858, 260.
Fusulina cylindrica, var. *ventricosa*, Meek & Hayden, ib., 261.

Shell fusiform, more or less ventricose in the middle, somewhat obtusely pointed at the extremities, which generally have the appearance of being a little twisted. Surface smooth excepting the septal furrows, which are moderately distinct, more or less regular, and a little curved as they approach the extremities. Aperture rather short, very narrow, and rarely visible as specimens are usually found. Volutions six to eight, closely coiled, the spaces between (near the middle) being rarely more than twice the thickness of the shell walls. Septa from twenty to about thirty-three in the last turn of adult specimens, counting around the middle; comparatively straight near their outer margins, but strongly undulated laterally within. Foramina passing through the outer walls of the chambers, distinct in well preserved specimens; as seen in transverse sections near the middle of the shell, somewhat radiating, and numbering in the outer turns of a medium sized shell, from twelve to twenty between each two of the septa.

Length (of a slender specimen), 0.37 inch; diameter, in the middle at right angles to the axis, 0.13 inch. Length (of a ventricose individual), 0.38 inch; diameter at right angles to the axis, near the middle, 0.20 inch. Types of figures and description, 1029, 1028.

The little shell described above, agrees so nearly with the figures and descriptions of *Fusulina cylindrica* of Fischer, that we are at a loss to find constant

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[1] Dr. Shumard describes a gigantic species attaining a length of two inches, from rocks in Texas supposed to be of the age of the Permian System of Europe (see Trans. St. Louis Acad. Sci. I, 397). From the description, however, we should suspect that it may belong to an allied, but distinct genus, since the aperture is said to extend the entire length of the shell.

characters by which it can be separated from that species; at any rate by the figures and descriptions we have yet seen. Still it is not improbable that a direct comparison with specimens of the Russian species would enable us to point out characters by which they could be distinguished. At one time we supposed that some ventricose specimens found by us in Kansas, might be separated as a variety from the more common slender forms; but further comparisons have satisfied us that they cannot be regarded as a sufficiently marked variety to make it desirable to designate them by a different name, there being every gradation between these two extremes. In case they should all, however, prove to be distinct from Fischer's species, the name *ventricosa* may be retained for the American type.

Locality and position.—The species here described ranges from Ohio to Kansas and southwestern Nebraska, and south to Texas. It seems to be more common, however, west of the Mississippi than east of it, and we have no knowledge of its existence east of Ohio. It probably occurs in western Kentucky, though we have never seen specimens of it from that State. It is common in portions of Missouri. At all the localities mentioned, it is found only in the Coal Measures.

The specimens here figured and described are from Juniata, on Kansas River, Kansas, where it occurs in great numbers.

MOLLUSCA.

Class **BRACHIOPODA.**

Family SPIRIFERIDÆ.

Shell free, inequivalve, varying greatly in form and ornamentation according to the genera and species; with or without a cardinal area; oral appendages large, provided with calcified, ribbon-shaped supports, which are spirally coiled so as to form two cones, the apices of which are directed outwards towards the lateral margins of the valves. Shell structure fibrous only, or fibro-punctate.

Animal unknown, apparently sometimes attached by a muscular peduncle.

Palæontologists generally place in this family all the Brachiopods known to possess calcified spiral oral appendages, however these appendages may be arranged or attached. We agree with Mr. Woodward and some others, however, in separating from it the genus *Atrypa*, which differs from the other genera usually placed in this family, in having the cones formed by its spiral oral appendages placed with their apices directed vertically instead of laterally, thus apparently indicating affinities to the *Rhynchonellidæ* (probably also including *Stenocisma*[1] and *Cœlospira*), in which the fleshy oral arms are similarly arranged.

The great differences of form and other characters presented by the other genera usually embraced in this family, render it also highly probable that they belong to more than one family; but as we can scarcely ever hope to know enough of the affinities of these extinct genera to successfully separate them, it is not probable that any attempt of that kind would meet with much favor. The entire family is, so far as known, extinct, and none of the genera appear to range above the Lias.

The groups falling within this family, as here defined, are *Trigonotreta*, *Martinia*, *Spirifina*, *Spirifer*, *Syringothyris*, *Cyrtina*, *Suessia*, *Trematospira*, *Spirigera*, *Merista*, *Pentagonia*,[2] *Nucleospira*, *Uncites*, *Retzia*, *Rhynchospira*, *Acambonia*, &c.

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[1] In the Fifteenth Report Regents University of N. Y., 1862, p. 154–5, Prof. Hall proposes the name *Zygospira* for a genus of which *Producta modesta*, Say, is the type. It seems, however, that Mr. Conrad had suggested for this shell the generic name *Stenocisma;* which Prof. Hall proposed in the first Vol. Pal. N. Y. (1847, p. 142) to adopt, should this type prove to belong to a distinct genus. As there was, therefore, no necessity for a new name, *Stenocisma* will have to take precedence over *Zygospira*.

[2] The name *Pentagonia* was proposed by Cozzens, in 1846 (Ann. Lyc. N. Hist., N Y., IV, p. 158), for a genus, or subgenus of peculiar angular Meristoid shells, of which *Pentagonia unisulcata* (=*Atrypa unisulcata*, Conrad, =*Pentagonia Persii*, Cozzens, =*Meristella* (*Goniocœlia*) *unisulcata*, Hall) is the type. In 1861, Prof. Hall suggests the name *Goniocœlia* for the same type (Fourteenth Rept. Regents University of N. Y., p. 101). Cozzens' name having priority, however, must be adopted for the group, whether we consider it a genus or a subgenus.

Genus SPIRIFER, Sowerby.

Synon.—*Hysterolites*, *Anomites* and *Terebratulites* (part) of early authors.
Terebratula (part), Lamarck, Prodr. 1799, 85 (not of authors generally).
Spirifer, Sowerby, Min. Conch. II, 1815, 42.
Trigonotreta, Kœnig, Icon. Sect. No. 70, 1825.—Bronn, Leth. Geog. 1837, 77.—King (part), Monog. Perm. Foss. England, 1850, 126.
Choristites, Fischer, Prodr. sur le Choristites Mosc. 1825, xx.
Delthyris, Dalman, Kongl. Vet. Ac. Handl. 1827.
Cyrtia, Dalman, ib., 1827.
Spirifera, Sowerby, Ind. to Min. Con. 1825; and of several later authors.
Martinia, McCoy, Synop. Carb. Foss. Ireland, 1844, 139.
Reticularia (part), McCoy, ib., 142.
Brachythyris, McCoy, ib., 144.
Ambocœlia, Hall, Thirteenth An. Rept. Regents University of N. Y., 1860, 71.
Etymol.—*Spira*, a spire; *fero*, to bear.
Type.—*Spirifer cuspidatus*, Sowerby.

Shell more or less triangular, semicircular, transversely elongate, or subglobose, with or without a mesial fold and sinus; lateral margins rounded, angular, or sometimes produced into mucronate, wing-like extensions; structure impunctate; surface plicate, costate, striate or smooth—sometimes roughened by minute granular or spinous projections. Cardinal line straight, as long as, or shorter than, the greatest transverse diameter of the valves. Hinge articulated by short teeth and sockets, and provided with a more or less developed cardinal area in each valve; that of the ventral valve being larger than the other, flat or arched, and generally inclined back over the hinge—divided by a triangular foramen usually more or less (sometimes entirely) closed by a false deltidium, which is occasionally pierced by a small circular or oval aperture near the beak; area of dorsal or smaller valve narrow, often linear, divided in the middle by a wide open fissure which is partly or entirely occupied by the cardinal muscular process. Beak of ventral or larger valve more prominent than that of the other, incurved or more or less nearly straight, that of the smaller valve short, and nearly always incurved.

In the interior of the dorsal valve the large spiral supports of the labial arms are attached by their crura to the hinge plates, some distance from which they are nearly or quite connected by a small process extending inwards from each. The cardinal muscles seem to have been attached to the cardinal process, under, and in front of which, the four large scars of the adductor muscles occur. In the larger or ventral valve the cardinal teeth are placed one on each side, and at the base of the foramen, and fit into corresponding sockets in the other valve; beneath the hinge these teeth are supported by the strong dental laminæ, which vary much in size and form, according to the species, and are supposed to have received on their inner sides the muscles of the peduncle. A considerable portion of the central region of this valve is occupied by the muscular scars, which are generally divided by a mesial ridge. Immediately on each side of this ridge occur the small longitudinally oval scars of the adductors, and outside of these the scars left by the cardinal muscles.

Some difference of opinion exists in regard to the particular species that should be considered the type of this genus. Most authors have fallen into the habit of viewing *Spirifer striatus* as the type, mainly, we believe, because Sowerby first discovered internal spiral appendages in that species, and had announced this discovery before the Linnæan Society in a paper read in 1814, but not published until during the following year, about the time the second volume of his Mineral Conchology, containing his description of the genus *Spirifer*, issued from the press. It is worthy of note, however, that he does not propose, in this paper, to establish a new genus upon *Spirifer striatus*—(which he there designates by the old name *Anomia striata*)—nor upon any other species, though he does allude to *Spirifer cuspidatus*, in a foot-note, appended some time between the reading and publication of the paper, as being figured in his Mineral Conchology as "*Spirifer cuspidatus*." So that even admitting that this paper was distributed a few months earlier than the second volume of his Mineral Conchology, *Spirifer cuspidatus* would still be the first species in connection with which we have any evidence he ever used the name *Spirifer*. It is also the first and *only* species described by him at the time that he founded the genus in the second volume of his Mineral Conchology, while he there makes no allusion whatever to the species *striatus*. It has been objected, however, that he admits in his remarks after the description of *S. cuspidatus*, immediately following the description of the genus *Spirifer*, that he only inferred from analogy, that this species possessed internal spires. In this inference, however, later discoveries show that he was correct; so that the name *Spirifer*, as well as all the characters mentioned in his description of the genus, are as applicable to *S. cuspidatus*, as to the species *striatus*. Hence we think that in accordance with the laws of priority *S. cuspidatus* should be regarded as the type of the genus.

We are not, however, in favor of so rigidly carrying out this rule as to invariably, and under all circumstances, regard the first species mentioned or described in connection with a new generic name, as its type, especially when that particular species may happen to present some important characters directly opposed to those given in the generic description, while another species described at the same time *does* exhibit these particular characters. But when an author describes a new genus, and at the same time describes but a single species, which presents all the characters given in the description, although he may have only inferred from analogy that it possessed some particular one of those characters he had not seen, we are compelled to regard that species as the type of the genus. The fact that he may have at some previous time seen this character in another form subsequently referred by him in another volume to the same genus, as Sowerby did with *Spirifer striatus*, cannot, we should think, invalidate the claims of the first species (*S. cuspidatus*) to be regarded as the type.

If we are right in these conclusions, Dalman's name *Cyrtia* becomes exactly synonymous with the genus *Spirifer*, since it was founded for the reception of species possessing precisely the characters of the typical forms of that genus; while the species usually viewed as typical Spirifers, must form a distinct sub-generic or generic group, to which Kœnig gave the name *Trigonotreta*, subsequently adopted by Prof. Bronn, and by Prof. King.[1]

As here defined and typified, it will be seen that this genus includes two rather marked sections, with one or more less distinctly defined groups, which may be characterized as follows:—

1. **Spirifer** (proper), SOWERBY, = *Cyrtia*, DALMAN, and others.

   Shell trigonal, nearly always costate or striate; hinge generally a little less than the breadth of the valves, more or less angular at the extremities; ventral valve very prominent or pyramidal; beak straight or a little curved; area large and triangular; foramen closed by a false deltidium, generally pierced by a small round or oval aperture near the apex of the beak; dorsal valve comparatively compressed, semicircular.

2. **Trigonotreta,** KŒNIG, = *Spirifer*, of most authors.

   Shell usually with both valves convex, marked as in the foregoing; lateral extremities generally angular, often acutely so; hinge line usually extended. Both valves with beaks more or less incurved; area variable in size, but rarely if ever so extravagantly developed as in some of the typical Spirifers; foramen open or more or less closed by a false deltidium without a perforation.

   Example.—Spirifer striatus, SOWERBY.

3. **Martinia,** McCOY, = *Ambocœlia*, HALL.

   Shell subglobose, or transversely or longitudinally oval, smooth or rarely with compressed rounded costæ; often beset with minute hair-like spines. Hinge short, scarcely ever equalling the greatest transverse diameter of the valves; lateral margins rounded, or rarely obtusely angular; beak of ventral valve incurved; cardinal area comparatively small; foramen, and false deltidium as in *Trigonotreta*.

   Type.—Spirifer glaber, SOWERBY.

The genus *Spiriferina* of D'Orbigny, is also often considered a subgenus under *Spirifer*. The coincidence, however, of a punctate structure in these shells, with the presence of a prominent mesial septum in the ventral valve, would seem to indicate important differences in the structure of the animal, such as would warrant its separation as a distinct genus.[2] So also with *Cyrtina* of Davidson, which was formerly included with the forms we here regard as the typical Spirifers, under the name *Cyrtia*. Mr. Davidson has, however, very properly separated these shells, on account of their punctate structure, and the peculiar development of the dental laminæ of the ventral valve, which are produced inwards, and coalesce into a single mesial septum, extending from the extremity of the beak, almost to the anterior margin, thus giving the interior more the appearance of *Pentamerus* than *Spirifer*. As Mr. Billings has, however, discovered internal spiral appendages in one of these shells, and they all possess a well-developed cardinal area, we cannot doubt the propriety of including them in the *Spiriferidæ*, though we think, as above stated, that they should constitute a distinct genus from all the other groups.

As thus freed from the punctate species, the typical Spirifers (= *Cyrtia*, Dalman) are found to pass by such insensible gradations into the *Trigonotreta* group (= the

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[1] In his valuable work on the Permian fossils of England, Prof. King regarded *Spirifer cuspidatus* as the type of the genus, and adopted Kœnig's name *Trigonotreta* for the shells generally considered typical Spirifers. It is said, however, that he subsequently changed his views in regard to the type of *Spirifer*.

[2] I avail myself of this opportunity to refer to the genus *Spiriferina*, a species described by me under the name of *Spirifera pulchra* (Proceed. Acad. Nat. Sci. July, 1860, p. 310), brought by Capt. Simpson from Nevada Territory. Sections of it show very distinctly a coarsely punctate, very finely fibrous structure; while casts of the interior exhibit a deep slit left by the mesial septum in the beak of the ventral valve—F. B. M.

usual type of *Spirifer* as generally understood), that we cannot see how the two can be separated more than as sections or subgenera.

It will therefore be seen, that in our present state of knowledge, it seems to be most natural to exclude entirely from the genus *Spirifer*, all the punctate species. Entertaining these views, it becomes necessary for us to explain why we have placed *Ambocœlia*, which has been described as "fibrous (or fibro-punctate)" with "lustre pearly," as a synonym of *Martinia*, one of the sections of *Spirifer*.

Our reasons are, in the first place, that we see nothing in the form and external appearances of the type of this proposed genus, to separate it from *Martinia;* especially since the closely allied *Ambocœlia gemmula*, of McChesney, which was also included by the author of *Ambocœlia* in that group, sometimes has its dorsal valve a little convex—indeed occasionally as much so as the scarcely distinguishable European *Spirifer Urei* and *S. Clanyanus*—though it is more frequently flat or concave as in the type of *Ambocœlia.* Again, we know from an examination of New York specimens of the type of *Ambocœlia*, in the collection of Mr. Worthen, State Geologist of Illinois, that it has internal spires arranged as in *Spirifer.* Thinking, however, that the punctate structure, and the supposed pearly lustre of this type, might warrant its separation, we subjected authentic specimens of it from the Hamilton Group, New York, to a careful microscopical examination, both in polished sections, and in thin broken fragments, and although we could distinctly see the usual fibrous structure so generally characteristic of the *Brachiopoda*, we failed to detect any traces of perforations, even by the aid of a high magnifying power.

In regard to the lustre, we think the word "pearly" must have been inadvertently written, or wrongly printed, for although fractured surfaces of this shell present a shining, somewhat silvery appearance, not unusual in the shells of fossil *Brachiopoda*, it cannot be said to be *pearly*, as that term is usually understood by Conchologists.

From these facts we do not feel prepared to admit *Ambocœlia* even as a distinct section from *Martinia*, until some more reliable differences can be pointed out.

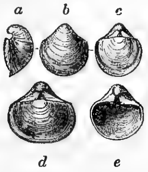
The genus *Spirifer*, as here characterized, commenced its existence during the Lower Silurian epoch, and ranges through the more modern formations into the Triassic rocks.

Spirifer (Martinia) plano-convexus.

Spirifer plano-convexus, Shumard, Report Geol. Survey Missouri, 1855, part Palæontology, 202.
Ambocœlia gemmula, McChesney, New Palæozoic Fossils, 1860, 41.
Ambocœlia gemmula, Hall, Thirteenth Report Regents University, N. Y. 1860, 71.
Comp. *Sp. Urei*, Fleming, Brit. Animals, 1828, 376.

Shell small, plano-convex or concavo-convex, young individuals usually longer than wide, adults wider than long; hinge line always shorter than the greatest transverse diameter of the valves; lateral margins and front rounded; surface apparently smooth excepting a few concentric marks of growth—but when examined with a magnifier, it is sometimes seen to be beset with the bases of minute hair-like spinules. Dorsal or smaller valve slightly convex near the beak, but usually concave around the front and antero-lateral margins, especially in adult individuals; truncato-orbicular in outline, usually very faintly depressed at the middle of the front; beak very small, not incurved, nor projecting beyond the cardinal margin; area about half as wide as in the other valve, flat, and standing nearly at right angles to the plane of the valve; foramen extending to the beak. Ventral valve strongly convex, sometimes very faintly flattened along the middle, but without a mesial sinus; beak very prominent, gibbous, and distinctly arched back over the hinge; area moderate, triangular, arched, well defined, and generally longer on the hinge side than the lateral margins; foramen usually higher than wide, provided with slightly raised lateral margins, not closed (so far as known) by a pseudo-deltidium. (Muscular impressions unknown.) Spiral appendages each consisting of six or seven distant turns.

Length of a large individual, 0.31 inch; breadth, 0.36 inch; convexity, 0.23 inch. Length of a young shell, 0.27 inch; breadth, 0.23 inch; convexity, 0.15 inch.



Spirifer (*Martinia*) *plano-convexus.*

a. Side view of medium sized specimen. *b.* Ventral view of same. *c.* Dorsal view of same. *d.* Dorsal view of a larger transverse specimen, showing the area and foramen. *e.* Hinge and internal view of a separated ventral.

This little shell seems to agree exactly with the species described by Dr. Shumard under the name *Spirifer plano-convexus*, and by Mr. McChesney, as *S. gemmula*, excepting that none of the (twenty or thirty) specimens we have seen show the faint mesial depression or sinus in the ventral or larger valve, mentioned by these gentlemen. As some of them, however, show a very slight flattening of the middle of this valve, it is probable other individuals may possess an obscure narrow sinus. It is worthy of note that the descriptions given by these gentlemen agree quite as well with the European *S. Urei*, and we are strongly inclined to the opinion that the form described by them, as well as that now before us, really belongs to that well known species. Still, as our specimens nearly all differ from all the figures of that species we have seen, in having the smaller valve, especially in adult examples, a little concave, and the ventral valve destitute of a mesial sinus, while they attain a much larger size, we have concluded to place them provisionally under Dr. Shumard's name *plano-convexus.*[1]

As the closely allied *Spirifer* (*Martinia*) *umbonatus* (= *Orthis umbonata*, Conr.), for which the new generic name *Ambocœlia* has been proposed, is described as having a "fibro-punctate" structure, we examined the structure of the species under consideration very carefully, by transmitted light under a high magnifying power, to see if we could detect the presence of punctures; but after repeated trials we failed to observe any traces of them, though we saw distinctly the usual fibro-prismatic structure.

Locality and position.—Manhattan, on Kansas River; Upper Mill Creek, and at various other localities in Eastern Kansas. Coal Measures. (Type of description and figures, 996, *a*, *b*, *c*.)

FAMILY PRODUCTIDÆ.

Shell free or attached by the substance of the beak, concavo-convex; valves articulated by teeth and sockets, or retained in place by the action of muscles only; hinge with or without a cardinal area; oral appendages without calcified supports, and probably fleshy and spiral; surface more or less spinous; substance fibro-punctate.

Animal unknown.

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[1] Since this was in type we have received a letter from Dr. Shumard, to whom we had sent the cuts of this species, in which he says he has no doubt of its identity with his *S. plano-convexus.*

This family includes the genera *Productus*, *Strophalosia*, *Aulosteges*, and *Chonetes*. It commences in the Silurian rocks, and ends with the Permian, being a strictly Palæozoic group.

Genus CHONETES, Fischer.

Synon.—*Pectenites*, *Pectunculites*, and *Pectunculus* (sp.) of the early authors.
Pecten, Ure, Hist. Ruthenglen, 1793, pl. xvi, fig. 10–11 (not Müller, 1776).
Hysterolites and *Terebratulites* (sp.), Schloth. Petref. 1820, 256, pl. xxix, fig. 3.
Productus (sp.), J. de C. Sowerby, Min. Conch. IV, 1823 (not 1815).—Buch (sp.), Abh. der K. Akad. Wiss. 1841, 33.
Leptæna (sp.), Goldf. Germ. Tr. de la Beche's Geol. 1832, 523 (not Dalm., 1828.)
Chonetes, Fischer de Wald. Oryckt. Moscou, 1837, 134.—Koninck, An. Foss. 1843, p. 206.; Id., Monogr. Mémoires Soc. Liege IV, 1847, 1.—Geinitz, Grundr. der Verstein. 1846, 517.—Hall, Palæont. N. Y., II, 1852, 64.
Strophomena (sp.), Hall, Geol. 4th Distr. N. Y. 1843, 72 and 180.
Etym.—χώνη, a little box.
Examp.—*Chonetes Dalmaniana*, De Koninck.

Animal unknown. Shell transversely semicircular, concavo-convex, compressed, greatest breadth usually on the hinge line; area common to both valves. Ventral valve convex, usually depressed along the hinge; area generally broader than that of the other valve, and inclined more or less back over the hinge—angular and armed along the margin with a row of tubular spines; foramen partly or entirely closed by a false deltidium. Dorsal valve concave; foramen replaced by a prominent bifid or trifid cardinal process. Surface of both valves sometimes nearly smooth, but generally ornamented by concentric marks of growth, and fine radiating striæ, or rarely large plications.

Hinge with two cardinal teeth, located one on each side of the foramen of the ventral valve, and fitting into corresponding pits in the other. Interior of both valves provided with a narrow more or less distinct mesial ridge, extending at right angles from the hinge, part of the way across, between the muscular impressions. Scars of the cardinal muscles in the ventral valve, ovate and somewhat oblique; those of the adductors very small, and placed between the impressions of the cardinal muscles and the mesial ridge. Dorsal valve with four small adductor muscular impressions, and two short linear hook-shaped vascular scars. Interior of both valves more or less granulated.

This genus was introduced during the Lower Silurian Epoch, and continued its existence at least to the close of the Carboniferous, in which it attained its maximum development.

Chonetes mucronata.

(Plate I, Fig. 5, *a*, *b*, *c*, *d*, *e*.)

Chonetes mucronata, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. 1858, 262.
Compare *C. Smithii*, Norwood & Pratten, Jour. Acad. Nat. Sci. Phila. 1857, 24, pl. ii, fig. 2.

Shell rather large, compressed, semicircular, having its greatest breadth on the cardinal border, which is extended into mucronate angles. Surface ornamented by a few subimbricating concentric marks of growth, crossed by very fine, obscure, regular, closely set radiating striæ, about one hundred and fifty of which may be counted around the border of large specimens, where eight or nine of them occupy the space of one line.

Larger or dental valve depressed, having usually a broad, very shallow undefined mesial depression extending from the front towards the beak; cardinal margin armed with from eight to twelve oblique spines on each side of the beak; area of moderate breadth; deltoid aperture very broad subtriangular, the upper angle being rounded and the margins more or less projecting; impressions of cardinal muscle subovate, diverging, attenuate above; adductor muscular scars small, narrow, subelliptical; mesial ridge small, slightly prominent, and scarcely ever reaching the middle of the valve.

Dorsal or smaller valve following nearly the curve of the other; beak and central region concave; ears flat; area well developed but narrower than that of the other valve, provided with mesial prominence, which, together with the small bifid cardinal process projecting from its inner side, nearly or quite closes the foramen of the opposite valve. From the base of this process there are extending on the inside of the valve five radiating ridges, two of which pass obliquely outwards along the inner margins of the dental pits, while a third extends at right angles to the hinge a little more than half way across towards the front of the valve; the other two ridges are much shorter and occupy intermediate positions between the central and lateral ridges, and are directed obliquely outward and forward. Interior of both valves more or less granulose, the larger granules being arranged over a semicircular belt a little within the border, which latter is occupied by very fine radiating granulose striæ.

Length, 0.62 inch; breadth on hinge line, 1.13 inch.

This shell is very closely allied to *Chonetes Smithii* of Norwood & Pratten, and may possibly prove to be only a variety of that species. It differs, however, in being generally much larger, rather more compressed, and proportionally longer on the hinge line; its ears are also often much more extended and pointed than those of *C. Smithii.* Another difference is that the coarser granules of the interior seem never to be scattered over the central region of the valves as in Norwood & Pratten's species. Again, the area of its smaller valve ranges more nearly at right angles to the plane of the shell than in Illinois species.

Locality and position.—Near Fort Riley, Kansas Territory. Coal Measures. (Type 1066.)

Family STROPHOMENIDÆ.

Shell attached or free; valves both convex, or one convex and the other flat or concave; hinge line straight, and provided with an area, which is common to both valves, but usually wider in the ventral than the dorsal valve; arms without calcified supports, being probably fleshy and spirally coiled; shell structure fibrous only, or fibro-punctate.

Animal unknown.

This family includes *Orthis*, *Hemipronites*, *Klitambonites*, *Strophomena*, *Leptæna* and *Tropidoleptus.* Some authors also include in it the genera *Chonetes* and *Porambonites*, but, as Mr. Davidson has demonstrated, the former belongs to the *Productidæ;* while the affinities of the latter remain somewhat doubtful.

This group presents one of the many interesting examples in the fossil world, of an entire family, embracing several genera, and a great number of species, which, after existing for immense periods of time, became entirely extinct, long before the dawn of the present epoch. It is mainly a Palæozoic family, since it appeared almost with the beginning of life, and became wholly extinct at the close of the Permian period, excepting the genus *Leptæna*, which continued to be represented by a few species until about the close of the Liassic period.

Genus HEMIPRONITES, Pander.

Synon.—*Terebratulites* (sp.), Schlot. Akad. Munch., VI, 1816, 28.
Hemipronites, Pander, Beitr. zur Geol. Russ. 1830, 75.
Klitambonites (part), Pander, 1830, Ib., 70.
Gonambonites, Pander, Ib., 1830, 77.
Spirifer (sp.), Phillips, Geol. York. 1836, II (not Sowerby, 1815).
Leptæna (sp.), J. de C. Sowerby, Min. Conch. 1840 (not Dalman, 1828).
Orthis (sp.), Portlock, Rept. Geol. Lond. 1843, 456.—Koninck. An. Foss. Belg. 1843, 222.—Hall, Geol. Rept. Iowa, I part ii, 1858, 640 and 713 (not Dalman 1828).
Orthisina (part), D'Orbigny, Compt. Rend. XXV, 1847, 267.—Davidson, Brit. Foss. Brach. I, Gen. Introduc. 1854, 104. *Orthisina* (sp.), Swallow, Trans. St. Louis Acad. Sci. I, 1858, 219.—Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 260.—Hall, Thirteenth Rept. Regents University N. Y. 1860 (not D'Orbigny, 1849).
Hemiprionites, Agassiz, Nom. Zool. Mol. 1846, 41.
Streptorhynchus, King, Permian Foss. England, 1850, 107.—Davidson, Brit. Permian Brachiopoda, 1857, 29.—Hall, Thirteenth Report Regents University N. Y., 1860, 112; also Sixteenth Rept. Dec. 1863, 61.
Etym.—ἡμι, half; πρών, prominence.
Type.—*Hemipronites tumidus*, Pander.

Shell varying from truncato-orbicular to semicircular, or orbicular subquadrate, more or less convex, the inequality of the valves varying greatly with the species; surface marked with radiating, generally straight striæ, and sometimes with rounded radiating plications. Hinge usually shorter than the greatest breadth of the valves; provided in the ventral or larger valve with two teeth, situated one on each side of the mesial fissure, and fitting into corresponding sockets in the other valve. Structure probably always impunctate.

Ventral valve with its beak more prominent than that of the dorsal, often bent or twisted, but not regularly incurved; area generally high, sometimes extremely so, its mesial fissure always closed, in adult shells, by a convex pseudo-deltidium. Hinge teeth supported within by two dental plates, which converge under the area towards the beak. Scars of cardinal and adductor muscles occupying about one-third to one-half the length of the valve (between the beak and the middle), and forming two elongated oval impressions, more or less deeply excavated, one on each side of a mesial ridge or septum.

Dorsal valve generally with its beak compressed and projecting little beyond the cardinal margin; area usually very narrow or rudimentary. Cardinal process large, prominent, and bifid; either slightly convex or concave on the inner side, with each division more or less grooved or emarginate at the extremity of the outer side; on each side of, and connecting with this, are the well-developed socket plates. At the bottom of the valve the quadruple scars of adductor muscles occupy about one-third the length of the valve, being arranged in pairs on each side of a short mesial ridge.

The shells belonging to this group, although usually regarded as constituting a section or subgenus of *Orthis*, present sufficiently marked differences to rank as a distinct genus. In the first place they differ in having the foramen always closed by a false deltidium, instead of being open, and hence they could scarcely have been attached by a peduncle, unless it may have been during the early stages of growth. Again, they have the beak of the ventral valve often much more produced, and more or less twisted or distorted as if from having been attached by the substance of the shell. They also have the dental laminæ of the ventral valve less prominent, and converging under the area towards the beak, instead of extending farther within the valve. The cardinal process of the other valve is likewise more developed, and the inner socket walls much less so. A still more important difference, if it should prove to be constant, as seems to be the case, is the merely fibrous shell structure in this group, and the fibro-punctate structure in *Orthis*.

This genus has also been confounded with *Klitambonites*, Pander (= *Orthisina*, D'Orb.), but Mr. Davidson has shown these two groups to be distinguished by well defined external and internal characters. For instance, in *Klitambonites* there is a well developed area, provided with a covered fissure in each valve; while in *Hemipronites* (= *Streptorhynchus*) the area of the dorsal valve is generally narrow or merely rudimentary. Again, in *Klitambonites* the false deltidium covering the fissure of the larger or ventral valve is pierced near the beak by a rounded or oval aperture never seen in *Hemipronites*. The beak of the ventral valve of *Klitambonites* likewise differs in never being twisted, as we often see in *Hemipronites*, and its area is generally more inclined towards the front of the shell. In the former group the cardinal process also differs in being formed of a single projection, with two small lateral depressions, and is covered by the false deltidium; while in *Hemipronites* this process is bilobate and exposed. These groups are likewise distinguished by differences in the details of the muscular impressions.

There are a few peculiar plicated shells, with a more or less distorted beak and a high triangular area provided with a closed fissure, found in the Coal Measures of Kansas and New Mexico, which appear to form a section of this group, though they may be generically distinct. *Orthisina missouriana* and *O. Shumardiana*, of Swallow—as well as *Streptorhynchus occidentalis* and *S. pyramidalis* of Newberry, are American examples of this type. *Productus eximius* of Eichwald, from the Carboniferous rocks of Russia, and *Streptorhynchus pectiniformis*, Davidson, from India, also belong to this plicated section.

This genus was first made known by Pander, in 1830, in the work cited in the synonymy at the head of this description, under the name *Klitambonites.* He included, however, under this name, two groups regarded by him as subgenerically distinct, the first of which he called *Pronites*, and the second *Hemipronites.* The typical species of his group *Pronites* (*P. adscendens*, Pander) being also the type of the including genus *Klitambonites*, the name *Pronites* must be regarded as merely a synonym of *Klitambonites*, since it would be an absurdity to retain a separate subgeneric name for the typical species of the including genus. In addition to this, the name *Pronites* had been used in 1811 for a genus of birds by Illiger.

The species *adscendens*, the type of *Klitambonites*, presents all the generic characters of the group to which D'Orbigny subsequently gave the name *Orthisina* ; while the typical species of the other supposed subgenus, *Hemipronites* (*H. tumidus*, Pander), is a true *Streptorhynchus* of King. Now, as these two names of Pander's clearly antedate those proposed by D'Orbigny and Prof. King, and there can be no doubt in regard to the types of Pander's groups, the law of priority compels us to adopt his names. The fact that he did not clearly define his genera, and proposed many species based upon mere varieties or individual modifications of a few species, is no reason for setting aside his generic names, when his figures and descriptions leave no doubts in regard to the genera to which his types belong.

The genus *Hemipronites* was first introduced during the deposition of the *Silurian* rocks; *H. deformis* (= *Orthis deformis*, Hall, Pal. N. Y., Vol. III, p. 174, pl. xiii, 3 a, b) and *H. Woolworthanus* (= *Strophomena Woolworthana*, Hall, ib., p. 192), from the Lower Helderburg rocks of N. Y., being Silurian examples of this group. The genus also occurs in the Devonian, Carboniferous and Permian rocks, probably attaining its maximum development in the Carboniferous. It seems to have become extinct before the commencement of the Triassic period, as we have no well authenticated knowledge of its existence in beds of that age.

Hemipronites arctistriatus, *H. alternatus* (= *Orthisina arctistriata*, and *O. alternata*, Hall, Thirteenth An. Rept. Regents University, N. Y., Dec. 1860, p. 80 and 81)[1] and *H. proximus* (= *Hipparionyx proximus*, Vanuxem, Rept. 3d Geol. Dist. N. Y., 1842, p. 124) are American examples of this genus from Devonian deposits.

Hemipronites crassus.

(PLATE I, Fig. 7, *a*, *b*, *c*, *d*.)

Orthisina crassa, MEEK & HAYDEN, Dec. 1858, Proceed. Acad. Nat. Sci. Phila. 260.

Shell of medium size, subquadrate, rather compressed, becoming thickened with age; hinge nearly or quite equalling the greatest breadth of the shell; front broadly rounded; lateral margins meeting the hinge nearly at right angles, sometimes slightly sinuous near the hinge. Surface ornamented by numerous straight radiating striæ, which number near the beaks some thirty or forty to each valve, but increase by the implantation of others between, so as to form one hundred to one hundred and twenty-four around the margin; crossing these striæ are numerous fine elevated concentric lines, which are not only quite distinct in the depressions, but on well preserved specimens are prominent upon the striæ, to which they impart a crenulated appearance, as seen by the aid of a lens. Adult specimens generally have also several strong concentric imbricating marks of growth.

Larger or ventral valve nearly flat; cardinal edge sloping a little to the lateral margins; beak somewhat prominent, and often distorted, or slightly twisted to one side; area flat, rather broad, and usually inclined backwards over the hinge—angular along its margins; pseudo-deltidium thick, prominent, nearly or quite closing the foramen; cardinal teeth not very prominent; scars of the adductor muscles large, separated by a sharp, rather prominent mesial ridge, and in old shells deep and well defined.

Dorsal valve moderately convex in the middle, and flat or concave on each side of the slightly convex umbo; cardinal process rather narrow. Interior of both valves marked by radiating striæ around the borders.

Length of a rather large specimen, 1.25 inch; breadth, 1.30 inch; convexity of the two valves, 0.46 inch.

At the time we first described this as a new species we had not seen accurate figures of several analogous European forms now regarded as varieties of *H. crenistria* (= *Spirifer crenistria* of Phillips). Since seeing Mr. Davidson's excellent figures and descriptions of the various forms now included by him under that name, we are led to doubt whether our shell is entitled to rank as a distinct species. Indeed, supposing *H. crenistria* to vary to the extent admitted, it would seem to be impossible to assign any very definite limits to such a protean species, and hence it

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[1] Prof. Hall subsequently, in a foot-note on p. 112 of the same Report, refers these species to *Streptorhynchus*.

would probably include our shell—which agrees very closely in form and surface-markings with some of those figured by Mr. Davidson. In form it seems to be most nearly allied to the species or variety *radialis* of Phillips, but differs in having its striæ of nearly uniform size. Internally it also differs from that and all the other analogous species or varieties, of which we have seen figures, in having the cardinal process of the dorsal valve proportionally narrower, and the socket plates less widely divergent. The muscular and visceral impressions of its ventral valve, as may be seen by our figures, occupy a proportionally larger space, extending out as they do about half the distance from the hinge to the front; while in the forms figured by Mr. Davidson, they only extend about one-third of the distance from the hinge to the front. These differences, however, may not be of specific value.

Locality and position.—Leavenworth City, Kansas, from a bed nearly on a level with the Missouri River. Coal Measures. (No. 1010.)

CLASS **LAMELLIBRANCHIATA.**

FAMILY PTERIIDÆ.

(= AVICULIDÆ.)

Shell inequivalve, inequilateral, composed of an inner laminated pearly layer, and an outer prismatic substance; left or upper valve always more convex than the other. Anterior margin of the right valve generally more or less sinuous for the passage of the byssus. Cartilage submarginal, simple, and placed in a single cavity or depression near the beaks, or divided and distributed in a series of furrows crossing the cardinal facet at right angles—or, in some of the older fossil genera (if distinct at all from the ligament), occupying linear furrows in the cardinal area or facet, ranging more or less nearly parallel to the hinge line. Hinge with or without teeth. Scar of adductor muscle large and usually sub-central; anterior muscular impression generally small and placed near the beaks, sometimes moderately developed. Pallial line simple, often irregularly dotted.

Animal, in the existing typical genus, with mantle margin freely open and doubly fringed; foot small, grooved, and having the power of spinning a byssus; palpi large; gills two on each side, crescent-shaped, free or connected with each other posteriorly, and to the mantle.

The above diagnosis is drawn up so as to include species belonging to three subordinate groups, the first of which, so far as known, has no living representatives, and seems to be mainly confined to the Palæozoic rocks. The other two groups (the *Pteriinæ* or *Aviculinæ*, and *Melininæ*) are both represented by living species in our existing seas. These three sections or subfamilies may be characterized as follows:—

1. Pteriniinæ (or *Pterinia* group).

Cartilage apparently occupying a series of linear furrows, ranging more or less nearly parallel to the cardinal margin, in a usually broad, flattened cardinal facet or area. Anterior muscular scar sometimes moderately developed and deep.

Includes *Pterinia*, *Myalina*, *Ambonychia*, and probably *Actinodesma*, *Gryphorhynchus*,[1] *Eurydesma*, and several undefined Palæozoic groups. A part of the species referred to the genus *Megambonia* (*M. aviculoides*, *M. lamellosa*, &c., HALL), will probably be found to belong to this subfamily, if not indeed to the genus *Pterinia*, while the typical species appear to belong to the family *Arcidæ*.

2. Pteriinæ (or *Aviculinæ*).

Cartilage mainly or entirely confined to a single more or less defined depression or cavity behind the beaks. Anterior muscular impression very small.

Includes *Pteroperna*, *Pteria* (or *Avicula*), *Margaritifera*, *Malleus*, *Aucella* and *Eumicrotis*.[2] The following extinct genera also probably belong here, viz.: *Monotis*, *Halobia*, *Pteronites* and *Possidonomia*, with apparently some undescribed fossil genera.

3. Melininæ (*Perna* or *Isognomon* group).

Cartilage divided and distributed along the hinge in a series of furrows crossing the cardinal area at right angles to the hinge line. Anterior muscular scar generally very small.

Includes *Crenatula*, *Melina* (= *Perna*, BRUG. not ADANSON), *Bakevellia*, *Gervillia*, *Inoceramus* and *Pulvinites*.

The first two of these sections seem to be more nearly related, in some respects, to each other, than either is to the third; and it is not improbable that they will be found connected by a few Triassic and Jurassic forms presenting intermediate characters, when the hinge and interior of a greater number of species are known. The Jurassic genus *Pteroperna*, for instance, has hinge teeth analogous to those of *Pterinia*, with apparently a cavity or depression for a cartilage, similar to that of *Avicula*. Such exceptional cases, however, cannot be urged as a reason for not admitting the convenience of sections or intermediate groups between families and genera, for it is highly probable that if we knew all the characters of all the species that ever existed, from the beginning of animal life to the present epoch inclusive, we would find all our groups blending imperceptibly together, or at least very far from being so sharply defined as they appear in works on natural history.

The *Pterinia* group, or subfamily, probably includes most of the Palæozoic species usually referred to *Avicula*, especially those from the Silurian and Devonian rocks. Indeed, we very much doubt the existence, during the deposition of the Palæozoic rocks, of true Aviculas, as that genus is known to Conchologists, and typified by the existing *A. hirundo*. At any rate, we have never seen a specimen, nor can we remember a figure, of any species showing the hinge of a true *Avicula*, from any of our American Palæozoic formations. All the Silurian and Devonian species with which we are acquainted, the hinge of which has been seen, appear to want the cartilage cavity of the modern Aviculas, and have the striated hinge facet, or the oblique hinge teeth (one or the other or both) of *Pterinia*, more or less distinctly marked. In addition to this, most of the Silurian and Devonian, as well as many of the Carboniferous species, the hinge of which is unknown, present more the external appearances of the European species figured by Goldfuss and others, in which the internal characters of *Pterinia* are known to exist.

Prof. McCoy some time since referred three of our American Palæozoic species—*A. demissa*, *A. pleuroptera* and *A. subfalcata*—to *Pterinia*; and the figures of *A.*

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[1] See American Journal Sci. and Arts (2d ser.), XXXVII, March, 1864, 217.

[2] Ib. 216.

securiformis, Hall, show traces of the broad striated area of that genus. *A. flabella*, Conrad, from the Hamilton group, has also been found to be a true *Pterinia.*[1] From all that is therefore known in regard to the affinities of these extinct shells, we may safely infer that probably all of our Silurian and Devonian species, usually referred to *Avicula*, especially those of the Hamilton and Chemung groups, will be found to possess the characters of *Pterinia*, or of undescribed genera.

It is a fact worthy of note, that while the existing genera of the family *Pteriidæ* or *Aviculidæ*, form a group at once so natural and distinctly defined that Conchologists meet with little difficulty in deciding what particular forms it should include, the boundaries of the family were not always so sharply marked. For, when we undertake to classify the numerous extinct genera that were introduced, lived out their term, and passed out of existence at various periods during the immense interval of time between the first introduction of this type of life and the present epoch, the case is very different; since we find amongst the vast numbers of fossil species, types presenting various intermediate gradations between the modern representatives of this and some of the allied families. For instance, no Conchologist could be for a moment in doubt whether any particular species or genus of our existing mollusks belongs more properly to the *Aviculidæ*, or to the *Pectinidæ.* Yet in tracing these two families, by their fossil shells, back into the distant past, we meet with various types presenting such an assemblage of characters as to often render their proper distribution more difficult; especially since we have only the light of analogy to guide us in our conclusions respecting the structure of the softer parts of these extinct forms. Some of these peculiar species were formerly referred by many Palæontologists to the genus *Pecten*, and by others to *Avicula;* and even now, since the genus *Aviculopecten* has been established for their reception, authors are by no means agreed whether this genus should be classed with the *Pectinidæ* or the *Aviculidæ.*

Again, no one having even a small amount of conchological knowledge, need be at a loss in deciding to which of the two families, *Arcidæ* or *Aviculidæ*, any of our existing species of bivalves belongs. Yet in passing from group to group of the *Arcidæ*, from the recent typical examples through some of the other modern forms, and thence through various extinct types, it will be observed that the hinge plates, or denticles, become more and more oblique, until in some of the Palæozoic genera, such as *Cyrtodonta*, *Vanuxemia*, *Dolabra*, &c., only a few obscure divisions are to be seen at the remote extremities of the hinge, ranging nearly or quite parallel to the cardinal margin, as in *Bakevellia*, *Pterinia*, and other genera apparently belonging to the *Aviculidæ.* In addition to this, in many of the extinct groups of *Aviculidæ*, such, for instance, as *Gryphorhynchus*, *Myalina*, *Bakevellia*, &c., there is as well a developed cardinal area, as we generally see in the *Arcidæ;* while this area in

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[1] See remarks on the family *Aviculidæ*, by F. B. Meek, Am. Jour. Sci. and Arts (2d ser.) Vol. XXXVII, March, 1864, 46.

several of these ancient types is provided with cartilage furrows, as in the *Arcidæ*. Again in *Pterinia*, and some species of *Bakevellia*, we see the anterior muscular impression comparatively so well developed, that one can scarcely believe it was not made by a true adductor; while the eccentric position of the posterior muscular impression would seem also to favor the same conclusion; and yet in all their other known characters these forms agree with the *Aviculidæ*.

In another direction, some of these ancient groups of *Aviculidæ* seem to show a disposition to shade off towards the *Mytilidæ* or *Dreissenidæ*. Amongst the Carboniferous and Permian species of *Myalina*, for instance, we see shells presenting apparently exactly the form and general external appearances of the existing genera *Mytilus* and *Dreissena*, to which even yet some Palæontologists will persist in referring them. On a closer inspection, however, these Carboniferous and Permian species, when we can find them with the two valves united, are seen to be always a little inequivalve, while their hinge also differs from that of the *Mytilidæ* and *Dreissenidæ*, in having a flat cardinal area, with longitudinal cartilage furrows. In addition to these differences, we have ascertained that the shell structure of at least two species of *Myalina* (*M. perattenuata*, M. & H., and *M. angulata*, Meek & Worthen) is minutely prismatic, as in true *Avicula*.[1] It is true the same structure has also been observed by Dr. Carpenter in the inner layer of *Dreissena;* but the unquestionable inequivalve character of *Myalina*, in connection with its peculiar cardinal area, and the fact that these shells are always found associated with marine types, are sufficient evidences that they have no very close affinities to *Dreissena*.

SUBFAMILY PTERINIINÆ.

Genus MYALINA, KONINCK.

Synon.—*Mytilus* (sp.), SOWERBY, and others (not LAMARCK, 1801).
Myalina, KONINCK, An. Foss. 1842, 125 (not CONRAD, 1845).
Aucella, GEINITZ, Dyas, 1861 (not KEYSERLING, 1846, nor MCCOY, 1855).
Etym.—? *Mya*.
Examp.—*Myalina lamellosa*, KONINCK.

Shell mytiliform, or subrhomboidal, extremely inequilateral, moderately inequivalve, more or less oblique; valves apparently a little gaping and slightly sinuous in front for the passage of the byssus. Beaks pointed and nearly or quite terminal; sometimes provided with an internal shelf or septum apparently for the attachment of the anterior muscle. Surface smooth or with concentric markings of growth, which, in some species, form imbricating laminæ. Hinge nearly or quite edentulous; ligament area usually broad, and marked by distinct cartilage? furrows parallel to the hinge line. Muscular and pallial impressions apparently as in *Pteria*.

Animal unknown.

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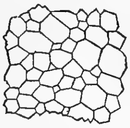
[1] See Am. Jour. Sci. XXXVII, March, 1864, 214.

Prof. Koninck described this genus as being equivalve—an error into which he was doubtless led by the distortion of his specimens. Prof. McCoy subsequently described it as inequivalve, which is undoubtedly correct, as we know from the study of our American species. As remarked by Prof. Koninck, the species often closely resemble *Mytilus* and *Perna* (Brug. not Adanson) in form; but the inequality of the valves, and the broad striated cardinal area, will distinguish them from the first—and the absence of deep vertical cartilage furrows in the hinge area, from the latter. They seem to be even more closely allied to the fresh-water genus *Dreissena*, with which some of the species agree exactly in form, excepting the slight inequality of the valves. They also sometimes possess an internal shelf or septum in each beak, as we see in that genus. We have likewise discovered that the shell structure is prismatic, as seen under a high magnifier, by transmitted light, as in the *Dreissenidæ* and *Aviculidæ*.

Were it not for the broad striated area, and the inequality of the valves, we would certainly be inclined, from all the facts, to place this genus in the *Dreissenidæ*, instead of the *Aviculidæ*. The prismatic structure of which we speak, settles the question in regard to these shells being distinct from the family *Mytilidæ;* but as this structure occurs both in the *Dreissenidæ* and the *Aviculidæ*, it is not alone so conclusive in regard to the relations of these shells to these two families. Further examinations, however, may yet enable us to decide this point, since in the *Aviculidæ* the inner layer of the shell is not prismatic, but pearly, and the outer layer only is prismatic; while in the *Dreissenidæ* there is no pearly interior—the inner layer being prismatic, as are the succeeding portions, excepting the very exterior. As the nacreous portion of shells is most frequently destroyed during the process of fossilization, it is difficult to determine very satisfactorily whether it was really the inner or outer layer in which we saw the prismatic structure—the shell being very thin, and apparently more or less exfoliated in the specimens examined. Our impression, however, is that it was the outer layer, or at any rate not the innermost; which would favor the conclusion that these shells belong to the *Aviculidæ*, as their inequivalve character, and broad cardinal area indicate.

The annexed cut shows the prismatic structure as seen in a fragment of *Myalina angulata*, placed in Canada Balsam, under a magnifying power of about 350 diameters.



Shell structure of *Myalina angulata*, magnified 350 diameters.

The genus *Myalina* seems to have been introduced during the latter part of the Devonian epoch, or soon after the beginning of the Carboniferous, and probably attained its maximum development during the deposition of the Coal Measures.[1] It also occurs in the Permian rocks, and may possibly range up into the Trias.

Myalina perattenuata.

(PLATE I, Fig. 12, *a*, *b*.)

Myalina perattenuata, MEEK & HAYDEN, Trans. Albany Institute, IV, March 2, 1858.

Shell very thin and fragile, obliquely elongate, narrow and slightly arcuate; valves convex anteriorly, and compressed behind. Beaks pointed, terminal and attenuate; hinge line equalling rather more than half the entire length of the shell, and ranging at an angle of about 50° above the oblique anterior margin. Posterior border sloping from the end of the hinge, nearly parallel to the anterior side above, and rounding to the narrow antero-basal extremity below; anterior margin of the valves a little arcuate, and rather abruptly deflected inwards from the umbonal ridge above the middle, and in outline nearly straight below. Umbonal slopes prominent from the beaks down the anterior side. Surface with obscure subimbricating marks of growth.

Length from the beaks to the postero-basal extremity, 1.50 inch; breadth, 0.65 inch; convexity, about 0.44 inch.

This species will be recognized by its slender attenuate form, and very thin shell. Like other species of the genus, it seems to have varied more or less in form, a portion of the specimens being straighter on the anterior margin than others. We know of no species with which it is liable to be confounded. *Myalina* (*Modiola*) *minor*, Lea (Jour. Acad. Nat. Sci. Phila., Vol. II, 2d ser., p. 205) seems to be an analogous species, but is more finely and regularly striated.

Locality and position.—Opposite the northern boundary of Missouri, on the Missouri River. From seams of yellowish magnesian limestone, in the Coal Measures. (Type 1022*a*.)

Myalina subquadrata.

Myalina subquadrata, SHUMARD, Geol. Report Missouri, part Palæontology, p. 207, pl. C, fig. 17, *a*, *b*.

Shell attaining a large size, compressed and somewhat alate in the postero-dorsal region, and convex anteriorly—considerably higher than long; posterior margin forming a broad gentle curve, being nearly straight and ranging almost vertically near the middle, and curving forward so as to intersect the hinge at an obtuse, undefined angle above, while below it arches regularly forward into the rather narrowly rounded base; anterior margin thickened within above, broadly arcuate or concave in outline, its curvature being nearly parallel to that of the posterior margin. Beaks terminal, directed forward; umbonal ridge most prominent and oblique above, and in adult shells curving downwards so as to range nearly vertically near the middle. Hinge line straight, and ranging nearly at right angles to the longer, or vertical axis of the valves; cartilage furrows distinct, straight, and in mature shells numbering about ten or twelve; area broad. (Muscular impressions unknown.)

Height about 4 inches; antero-posterior diameter at the middle, 2.40 inches; convexity of a left valve, 0.83 inch.

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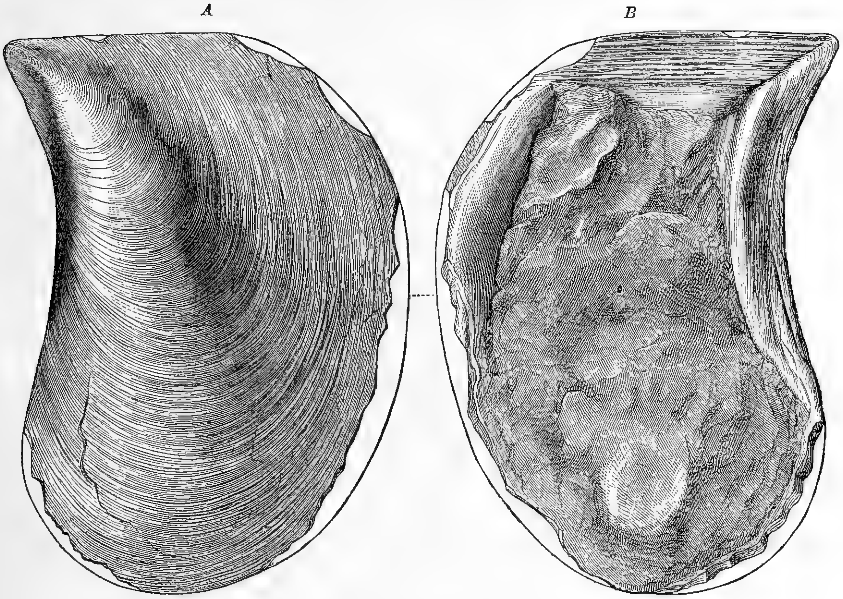
[1] Prof. Hall refers an Upper Silurian shell, from the Clinton Group (Pal. N. Y. Vol. II, p. 100, pl. xxx), to this genus; but as his specimen is an imperfect cast, its true relations remain doubtful.



Myalina subquadrata.

A. Outside of a left valve somewhat weathered. *B.* Hinge view of same.

In size and general appearance this shell resembles *Myalina subquadrata*, of Shumard, to which we have concluded to refer it provisionally, on the authority of Dr. S., to whom we sent the above cuts for comparison. It will be observed, however, on comparing our figures with those of the typical specimen of *M. subquadrata*, published in the Missouri Report, that our shell differs in having its posterior margin curving forward above, so as to intersect the hinge (as may be seen by the direction of the lines of growth) at an obtuse undefined angle, instead of being nearly straight and intersecting the hinge at right angles. This peculiarity gives a different expression to the posterior outline of the shell, that had led us to think it probably distinct. Should it be found, when we can have an opportunity to compare a series of specimens, that this difference is constant in adult examples, the propriety of separating these two forms can scarcely admit of a doubt, in which case the form under consideration may be designated as *Myalina ampla.*

Locality and position.—Leavenworth City, Kansas, from a thin layer of impure limestone near the level of the Missouri River. Coal Measures. (Type No. 998.)

FAMILY CRASSATELLIDÆ.

Shell generally thick and strong, equivalve, oblong, oval, subcircular or subtrigonal. Surface covered with a brownish epidermis, and often ornamented with radiating or concentric costæ. Hinge with generally strong cardinal teeth; ligament external or internal. Muscular impressions usually deep and well defined; pallial impression simple or very slightly sinuous.

Animal (in the typical genus) with mantle lobes only united by the branchial septum; margins of inhalent orifices cirrhated; foot moderate, compressed, more or less triangular, and grooved. Palpi triangular; gills unequal, outer semi-lunar, inner widest anteriorly.

Authors differ in regard to the limits of this family, some including in it several genera which others refer to the *Veniliidæ*[1] (=*Cyprinidæ*), or to some of the allied families. The existing genera most generally placed here, are *Astarte*, *Gouldia*, *Crassatella*, *Cardita*, *Carditamera*, *Thecalia*, *Trapezium*, *Coralliophaga*, &c. It also includes the following extinct groups, viz.: *Venericardia*, *Pachydomus*, *Astartella*, *Cardinia*, *Carbonocola*, *Astartila*, *Pachycardia*, *Pachyrisma*, *Megalodon*, *Mecynodon*, *Hippopodium*, *Myoconcha*, *Opis*, *Pleurophorus*, *Cleidophorus*, *Erycinella*, *Woodia*, *Lutetia*, and probably *Cypricardella*, *Matheria*, *Cypricardina*, *Anodontopsis*, *Curtonotus*,[2] &c.

Genus PLEUROPHORUS, KING.

Synon.—*Nuculites* (sp.), CONRAD, Ann. Report Geol. N. Y. 1841, 48.
Pleurophorus, KING, Ann. Mag. Nat. Hist. XIV, 1844, 313.—DE VERNEUIL, Bull. Soc. Geol. Fr. 1844 (2d ser.), 1.—KING, Monogr. Perm. Foss. Eng. 1850, 180.
Cleidophorus, HALL, Palæont. N. Y. I, 1847, 300.
Clidophorus, MCCOY, Palæozoic Fossils, 1852, 273.
Etym.—πλευρόν, a rib; φέρω, to bear.
Type.—*Arca costata*, BROWN.

Shell generally small, longitudinally oblong or subovate, inequilateral; cardinal teeth two in each valve, interlocking alternately, and more or less divergent; posterior lateral teeth one to each valve, the receiving tooth in the left valve. Anterior adductor muscular scar deep, and bounded posteriorly by a ridge; pallial line simple.

This genus may be distinguished from *Cardita*, by its depressed, elongate form, as well as by its upper cardinal tooth in the right valve being elongated posteriorly, and by having true posterior lateral teeth. From *Cypricardia*, and *Carbonocola*, it differs in having the receiving tooth in the left, instead of the right valve. From *Carditamera*, with which it agrees in the arrangement of the lateral teeth, it differs

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[1] The name *Cyprinidæ* having been long in use for a family of fishes, ought not to be retained for this group.

[2] It is desirable that the author of this genus should select another name for it, *Curtonotus* having been used by Hann for a genus of *Crustacea*, in 1835.

in having a short upper cardinal tooth; and in being destitute of anterior teeth. It also resembles *Coralliophaga*, from which, however, it is clearly distinguished by its simple pallial line.

Prof. McCoy, who has had an opportunity to compare typical specimens of *Cleidophorus*, with examples of *Pleurophorus* showing the hinge, says they agree exactly in their dentition, and it is on his authority that we here regard them as synonymous. Our description of the hinge is taken from Prof. King's carefully written description of *Pleurophorus*.

Prof. Hall's name, however, may, we think, be properly retained in a subgeneric sense, for a section of this group probably confined to the Silurian rocks. This subgenus may be distinguished from the typical costated species found in the more modern formations, by the following characters:—

Cleidophorus, Hall.

Shell without radiating postero-dorsal costæ. Internal ridge bounding the scar of the anterior adductor, descending with a slight forward slope.

Type.—*Nuculites planulata*, Conrad.

The genus *Pleurophorus*, as here defined, was introduced during the Lower Silurian epoch, where it was represented by the smooth species. It also ranges through the Carboniferous and Permian rocks, as stated above, into the Trias, the more recent species being the typical forms.

Pleurophorus occidentalis.

(Plate I, Fig. 11, *a*, *b*.)

Pleurophorus? occidentalis, Meek & Hayden, Trans. Albany Institute, IV, March 2, 185.

Shell small, narrow, somewhat elongate; valves moderately convex along the umbonal slopes. Basal and dorsal margins nearly straight and subparallel, or converging slightly toward the front; posterior side rounded, and rather compressed; anterior side rounding up gradually from the base. Beaks small, depressed, and located at the anterior extremity; hinge line long and straight. Surface with a few concentric marks, and traces of finer lines of growth, which are crossed by some four or five small faintly defined radiating costæ, extending from the beaks obliquely backwards and downwards to the posterior, and postero-basal margins.

Length, 0.37 inch; height, 0.16 inch; breadth, or convexity of the two valves, about 0.14 inch.

Not having seen the hinge or interior of this little shell, we are not sure it really belongs to the typical group *Pleurophorus*. It agrees, however, so nearly in its external characters, with *P. costatus*, as figured by Prof. King in his work on the Permian fossils of England, that we are strongly inclined to think it will be found to possess a similar hinge. Specifically, it differs from *P. costatus*, in being much smaller, more depressed, and more contracted in the antero-ventral region.

Locality and position.—Nebraska, nearly opposite the northern boundary of Missouri. Coal Measures. (No. 1017.)

Family ANATINIDÆ.

Shell thin, often inequivalve, inequilateral, more or less gaping posteriorly, pearly within. Surface, in well preserved specimens, generally granulose, concentrically or radiately striate or costate. Hinge teeth usually rudimentary or obsolete; ligament external, thin; cartilage occupying an internal pit or cavity under the beak of each valve, and usually provided with a free ossicle. Beaks sometimes fissured. Muscular impressions faint; pallial line generally sinuous.

Animal with long, more or less separated siphons, which are fringed at the extremities; mantle with united margins, provided with a valve-like opening under the siphons; gills single on each side, pinnate—outer laminæ prolonged dorsally beyond the line of attachment.

A number of fossil genera appear to belong to this family, though their affinities have not been very clearly determined. It is possible some of those mentioned below may belong to one or more distinct families; but until their relations can be made out more satisfactorily, from the study and examination of the hinge and interior of a larger number of species, we prefer to place them here.

The existing genera, properly included in this group, are *Anatina*, *Periploma*, *Thracia*, *Lyonsia*, *Mytilimeria*, *Poromya*, *Myodora*, *Pandorella*, *Cœlodon*, *Pandora*, *Clidiophora*, *Theora*, *Neæra?* *Tyleria*, and *Pholadomya*.

The extinct groups, apparently belonging here, are *Margaritaria*, *Cercomya*, *Anatimya*, *Allorisma*, *Myacites*, *Homomya*, *Anthracomya?* *Chœnomya*, *Platymya*, *Arcomya*, *Mactromya*, *Goniomya*, *Gresslya*, *Cardiomorpha*, *Ceromya*, *Sedgwickia*, *Sanguinolites*, and probably *Cleobis* and some of the species included in the genus *Orthonota*.

Genus ALLORISMA, King.

Synon.—*Sanguinolaria* (*gibbosa*), Sowerby, Min. Conch. VI, 1814, 92.
Myacites (sp.), Schlot. ? Petrefact. 1820, 176.
Hiatella (*sulcata*), Fleming, Brit. An. 313.
Pholadomya (*elongata*), Morton, Am. Jour. Sci. XXIX, 1836.
Sanguinolites (part), McCoy, Carb. Foss. Ireland, 1844, 47.
Allorisma, King, Ann. Mag. Nat. Hist. XIV, 1844, 315; Mon. Permian Foss. England, 1850, 196.
Etym.—ἀλλοῖος, variable; ἔρεισμα, support.
Examp.—*Hiatella sulcata*, Fleming.[1]

Shell equivalve, inequilateral, elongate, thin; anterior side short; posterior side long and somewhat gaping at the extremity; beaks depressed, anterior. Surface minutely granulose, and ornamented with more or less distinct concentric ridges

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[1] As first defined by Prof. King, this genus was made to also include species belonging to the genus *Edmondia*. We observe that he remarks in a foot-note to page 196 of his Monograph of the Permian Fossils of England, published in 1850, that he avails himself of that opportunity to name *Hiatella sulcata* as the type of this genus, instead of *Allorisma regularis* of Murchison, Verneuile & Keyserling's work on the Fossils of Russia; because he thinks the latter more probably an *Edmondia*.

or undulations. Hinge edentulous; ligament apparently wholly external. Dorsal margin inflected so as to form a lanceolate depression or false area along the cardinal border behind the beaks. Scar of anterior adductor muscle occupying a comparatively low position. Pallial line faintly marked; its sinus sometimes deep, rounded or angular.

Animal unknown.

We are rather at a loss to find well marked and constant external characters by which the shells of this genus can be always readily distinguished from some of the Triassic and Jurassic forms usually referred to *Myacites*, and included by Prof. Agassiz in the groups for which he proposed the names *Pleuromya* and *Myopsis*. Indeed some of our Devonian and Carboniferous species, if found in Triassic or Jurassic rocks, would be at once referred to *Myacites*, *Pleuromya*, or *Myopsis*, by most Geologists. As observed by Prof. Agassiz, the shells included by him under the latter two names are very closely allied, and it was mainly in consequence of the presence of cardinal teeth, and a granulated surface in several of the species of *Myopsis* (characters not observed in those referred to the group he called *Pleuromya*), that they were separated. Some subsequent European investigators, however, say they find these characters common to species included in both groups. If these observers are not mistaken, these two groups should probably be united under the older name *Myacites*, from which the genus under consideration would be mainly distinguished by its edentulous hinge. The Allorismas are, however, also generally longer shells, with more depressed beaks, and they were probably never so widely gaping behind as some species of *Myacites*.

From the genus *Pholadomya*, to which this group is related, it can always be distinguished by the total absence of the radiating costæ so characteristic of that genus. They likewise differ in the granulated character of the surface, though it is rather rarely the case that we find specimens in a condition to show this latter peculiarity.

The genus *Allorisma* appears to have been first introduced during the Devonian epoch, and attained its maximum development before the close of the Carboniferous. It also occurs in the Permian rocks, and, as already stated, some very similar forms have been described under the name of *Myacites* from the Triassic and Jurassic rocks.

Allorisma subcuneata.

(Plate I, Fig. 10, *a*, *b*.)

Allorisma subcuneata, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 263.
Comp. *Sanguinolites clava*, McCoy, Brit. Pal. Foss. 1852, Fasc. III, 504, pl. 3 F, fig. 12.

Shell large, clavato-cuneate, gibbous in the anterior and umbonal regions; narrowed and compressed posteriorly. Beaks depressed, incurved, and located about one-eighth the entire length of the shell from the anterior extremity. Posterior end narrowly rounded, and apparently moderately gaping; anterior end obliquely subtruncate above, and rather narrowly rounded and somewhat produced below; basal margin nearly straight along the middle, contracting

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This, however, was unnecessary, since he had distinctly stated in first publishing the genus in the Annals and Mag. Nat. Hist. Vol. XIV, 1844, p. 315, that it "is represented by *Sanguinolaria sulcata* of Phillips."

very gradually behind, and rounding up more abruptly in front; dorsal margin nearly parallel to the base, or declining a little posteriorly. Surface of internal casts marked by rather small, moderately distinct concentric undulations, which are quite regular over the umbones, but become more irregular and obscure towards the margins of the valves.

The hinge is long, and nearly straight. In casts there is a rather narrow depression extending along its entire length, bounded on either side by an obtuse ridge, ranging parallel to the hinge line. Immediately outside of each of these ridges there is a shallow rounded sulcus, which is widest near the posterior muscular scar, and becomes narrower, and less distinct towards the beaks. The anterior muscular impression is well defined, transversely lunate in form, and connected with the pedal scar above in such a manner that the two together present much the appearance of a capital letter G, lying on its back. The posterior muscular scar is large, broad rhombic-subovate in form, and placed near the hinge, about one-third the entire length of the shell from the posterior extremity. The pallial line is faintly marked, and apparently provided with a deep acutely angular sinus.

Length, 5.10 inches; height, 2.25 inches; greatest thickness or convexity near the anterior end, 1.70 inch.

This species is very closely allied to *Sanguinolites clava*, of McCoy (cited at the head of this description), and may possibly prove to be identical, when a direct comparison of specimens can be made. Those we have yet seen, however, of the Kansas fossil, differ from Prof. McCoy's figures in being straighter on the dorsal margin, and more produced, as well as more narrowly rounded in the antero-ventral region. Their concentric undulations are also more obscure, and the lunule-like depression in front of the beaks less distinctly defined, in our shell.

Locality and position.—Leavenworth City, Kansas, from a bed holding a position a few feet above low-water mark of the Missouri. Coal Measures. (Type 1020.)

Genus SEDGWICKIA, McCoy.

Synon.—*Sedgwickia*, McCoy, Synopsis Carb. Foss. Ireland, 1844, 61.
Leptodomus, McCoy, British Pal. Foss. 1852, 277 (not 1844, Carb. Foss. Ireland, p. 66).
Sanguinolites (part), McCoy, Brit. Pal. Foss. 1852, 276 (not Carb. Foss. Ireland, 1844, p. 47).
Etym.—Dedicated to Rev. Adam Sedgwick, M. A., F. R. S.
Type.—*Sedgwickia attenuata*, McCoy.

Shell depressed oblong, or suboval, nearly or quite equivalve, inequilateral, very thin; anterior side not quite closed, often a little gibbous; posterior side longer, more compressed, and more widely gaping. Beaks prominent, rather tumid, incurved; posterior umbonal slopes prominently rounded, or sometimes forming an oblique ridge, generally separated from the compressed postero-dorsal region by a shallow, linear sulcus, which is also sometimes marked on internal casts. Flanks compressed, or somewhat concave in the antero-ventral region, or a little behind it. Lunular impression distinct. Surface finely granulose, and ornamented with more or less regular concentric ridges and striæ, the ridges being usually obsolete on the posterior and compressed postero-dorsal portions of the valves. Hinge edentulous; cardinal margin inflected so as to form a narrow false area behind the beaks. (Muscular and pallial impressions very obscure and not well known; animal unknown.)

This group, as here defined, agrees in all essential characters with *Leptodomus*, as characterized in 1852 by Prof. McCoy, in his beautiful work on the British Palæzoic Fossils. We think, however, that this name cannot be retained, in accordance with the established rules of nomenclature, for these shells, because the type of the genus *Leptodomus*, as originally founded by Prof. McCoy (*L. fragilis*, Carb. Foss. Ireland, 1844, 66), apparently belongs to an entirely different group. On turning to Prof. McCoy's figure of this species (Ib. pl. x, fig. 11), it will be seen to be a short, high, ventricose shell, with gibbous distinctly incurved beaks, and a nearly smooth, or merely striated surface, and rather well marked muscular impressions. Indeed we are led by Prof. McCoy's figure and description to think this shell not generically distinct from some of the forms included by Prof. Koninck in his genus *Cardiomorpha*, though it may be a *Schizodus*, King.

On the other hand, we think the shells under consideration, are not generically distinct from *Sedgwickia*, McCoy, as originally proposed by him in his Synop. Carb. Foss. 1844, p. 61, and typified by his *S. attenuata* (Ib. p. 62). It may be, however, that Prof. McCoy dropped the name *Sedgwickia*, because it had been used several times in Botany. Still we cannot regard this as a sufficient reason for setting the name aside, for there are numerous instances where the same name is retained for genera in Botany and Zoology. In addition to this, the particular genus for which Botanists now retain the name *Sedgwickia*, was published by Griffith, since the publication of Prof. McCoy's genus. Even if we admit, however, the propriety of abandoning the name *Sedgwickia*, these shells cannot be properly referred to *Leptodomus*, we should think, until it can be demonstrated, or at least rendered probable, that they are congeneric with the type of that genus—*L. fragilis*, McCoy.

It is worthy of remark, also, that these shells resemble the typical Allorismas in so many points that we have some doubts whether they should be separated more than as a sub-genus. They are also rather closely allied to *Myacites*, as affirmed by Munster. From the typical species of the former genus, they differ in being shorter and usually more gibbous shells, with more prominent beaks and umbonal slopes. They also differ in having the postero-dorsal region more compressed, and the cardinal margin more concave in outline behind the beaks. These peculiarities give these shells a *Lyonsia*-like aspect apparently never seen in the true Allorismas. In their less elongated form, and more prominent beaks, they approach nearer some species of *Myacites*, but differ in the other characters mentioned.

From the genus *Sanguinolites*, as originally defined, and typified by *Sanguinolaria? angustata* of Phillips (McCoy, Carb. Foss. Ireland, 1844, 47 and 48), our shells differ in being proportionally much shorter, more gibbous, less depressed, and not near so straight and parallel on their dorsal and ventral margins. Until something, however, can be determined in regard to the hinge or muscular and pallial impressions of *Sanguinolites angustatus*, the type of that genus, we can form no satisfactory conclusions in regard to its limits. It is true, Prof. McCoy, in re-describing this genus, in his Brit. Pal. Foss. 1852, describes the muscular and pallial impressions; but it is manifest these characters were taken from his *S. iridinoides*, and other forms, that may or may not be congeneric with the species *angustatus*. Should the *S. iridinoides*, however, really be congeneric with that species, which is not improbable, it would rather confirm the conclusion that the short gibbous shells under consideration are generically distinct, than the contrary.

The following species seem to be congeneric with the original type of *Sedgwickia*, viz.: *S. costellata* (= *Sanguinolites* (*Leptodomus*) *costellatus*, McCoy, Brit. Pal. Foss. pl. 3, F, fig. 5); *S. variabilis* (= *Sanguinolites variabilis*, McCoy, ib. fig. 6); *S. truncata* (= *Leptodomus truncatus*, McCoy, ib. pl. 1, K, fig. 21 and 24), and *S. granosa* and *S. topekaensis* (= *Leptodomus granosus* and *L. topekaensis*, Shumard, Trans. St. Louis Acad. I, p. 207–8).

If we are right in referring *Leptodomus truncatus*, McCoy, to this genus, it would carry back the origin of the group at least to the Upper Silurian epoch. Some similar forms also occur in the Devonian rocks, and the genus probably attained its greatest development during the deposition of the Carboniferous Series. Several species presenting very similar external appearances have also been described under the names *Myacites*, *Cypricardia*, &c., from the Triassic and Jurassic deposits; but we have little or no knowledge of the true affinities of many of these shells, and consequently cannot pretend to define, with precision, the geological range of the genus *Sedgwickia*.

Sedgwickia topekaensis?

Leptodomus Topekænsis, Shumard, Trans. St. Louis Acad. Sci. I, 1858, 208.

Shell depressed subovate, about twice as long as high, extremely thin and fragile, gibbous in the region of the beaks, and along the oblique umbonal slopes. Sides flattened above, and becoming a little concave towards the base in front of the middle. Dorsal border nearly horizontal, and slightly concave in outline behind the beaks, where its inflected edge is margined by a rather distinct ridge; ventral border presenting a broad semi-ovate outline, excepting a very slight sinuosity just in advance of the middle—rounding up abruptly in front and more gradually behind; anterior side prominent, gibbous, and narrowly rounded below, obliquely truncated above; posterior side compressed, narrowed, and apparently subtruncate and somewhat gaping at the extremity. Lunular impression in front of the beaks (in casts) moderately distinct, defined by a faintly impressed line. Beaks prominent, gibbous, a little flattened, incurved, and placed between the middle and the anterior extremity, but nearer the former.

Entire surface, in well preserved specimens, closely covered with minute granules arranged in radiating rows; and ornamented with small concentric ridges, which are most regular and distinct on the umbones, and end abruptly along an impressed line extending from the posterior side of each beak obliquely towards the postero-basal margin, thus leaving the compressed postero-dorsal region comparatively smooth. (Muscular and pallial impressions unknown.)

Length about 2 inches; height, 1 inch; convexity, 0.75 inch.

Sedgwickia topekaensis?

A. Dorsal view, partly restored, one valve being distorted in the specimen. *B*. Side view of same.

This shell is closely related to *S. granosa* (*Leptodomus granosus*, Shumard), but seems to agree more nearly, when all its characters are taken into consideration, with the form described by him under the name *Leptodomus topekaensis;* particularly in the possession of a shallow linear sulcus extending from the back part of each beak, towards the postero-basal margin. It is true, Dr. S. does not mention the presence of fine granules on the surface of the species *Topekaensis*, while this is one of the characters of his *granosa.* The apparent absence of granules, however, on the former may be due to the condition of the specimen, as this is a character easily obliterated by wearing. Of the known foreign species, its nearest representative is perhaps *Sanguinolites variabilis*, McCoy (Brit. Pal. Foss. pl. 3, F, fig. 6–7), from which it differs in being much narrower posteriorly, and in having a proportionally longer hinge line, particularly as compared with adult specimens of McCoy's species. Its antero-ventral region is also more prominent than that of *S. variabilis.*

Locality and position.—Leavenworth City, Kansas; it occurs both in the hills back of the town, 200 to 250 feet above the Missouri, and in beds of impure limestone near the landing, little above the level of the river. Coal Measures. (Type No. 1011.)

Sedgwickia? concava.

(Plate I, Fig. 8, *a*, *b*.)

Lyonsia concava, Meek & Hayden, Trans. Albany Inst. IV, March 2d, 1858.

Shell small, elongate-oval; valves moderately convex in the umbonal and anterior regions. Extremities rounded; posterior end compressed, apparently a little gaping; base nearly straight along the middle, and rounding up at the extremities; dorsal outline concave behind the beaks—declining in front. Beaks rather depressed, incurved, and located about half-way between the middle and the anterior extremity. Surface of casts with a few more or less distinct marks of growth. (Hinge, muscular and pallial impressions unknown.)

Length, 0.65 inch; height, from base to top of beaks, 0.30 inch; convexity, 0.23 inch.

In first publishing a description of this species, we placed it provisionally in the genus *Lyonsia*, stating, at the same time, that our specimens were merely casts, and that we were consequently left in doubt in regard to its generic relations. Subsequent examinations of other specimens have satisfied us, however, that it can scarcely be a *Lyonsia*—there being no impressions in well preserved internal casts, of the projecting cartilage plates so characteristic of that genus. This being the case, we now place it with doubt, in the genus *Sedgwickia*, to which it appears to be more nearly related; but in so doing, we should remark that until specimens showing the hinge, and other internal characters can be examined, its true affinities cannot be determined with any degree of confidence.

Locality and position.—Nebraska, opposite the northern boundary of Missouri. Coal Measures. (Type No. 1023.)

Sedgwickia? altirostrata.

(Plate I, Fig. 9.)

Allorisma? altirostrata, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 263.

Shell longitudinally oblong-oval, very gibbous in the umbonal region; beaks elevated above the cardinal margin, incurved, and located almost directly over the anterior edge. Posterior side rather broadly and regularly rounded, apparently gaping; anterior side subtruncate, a little gaping, and rounding into the base below; ventral border nearly straight, or somewhat concave in outline near the middle, and rounding up at the extremities. Cardinal margin straight, rather short. Surface of cast ornamented by concentric undulations, which are small, regular, and well defined on the umbonal slopes, but become less distinct, and more irregular near the margins of the valves. Just in front of the most prominent part of the oblique umbonal ridge of each valve there is a moderately distinct, narrow, undefined sulcus, extending backwards and downwards to the middle of the base.

Length, about 3.06 inches; height, from the base to the dorsal margin, 1.57 inch; do. to the highest part of the beaks, 1.74 inch; greatest convexity of the two valves, 1.62 inch.

It is only provisionally we place this species in the genus *Sedgwickia*, not having seen any specimens showing the hinge; while the form of the shell is different from that of the typical species, the nearly terminal position and greater elevation of the beaks giving it much the physiognomy of many species of *Pholadomya.* Indeed, it only wants radiating costæ to present all the *external* characters of that genus. It is more nearly related to *Pholadomya Omaliana*, Koninck, than to any other shell with which we are acquainted, from any part of the Carboniferous system. Yet it differs in having more elevated, and rather more nearly terminal beaks, as well as in the possession of an oblique sulcus in front of the umbonal slope of each valve. The concentric undulations are likewise more distinct and regular on its flanks, and its antero-ventral region is less prominent.

It is probable that this shell will be found to present internal characters warranting its separation, either as a sub-genus, or as a distinct genus, from Sedgwickia. If so, we would propose for the group the name *Exochorhynchus* (εξοχος, prominent; ʽϱίγχος, beak). It would include *E.* (*Pholadomya*) *Omaliana*, of Koninck.

Locality and position.—Juniata, on Big Blue River, Kansas. Coal Measures. In the paper cited at the head of this description, Grasshopper Creek was, by some oversight, erroneously given as the locality from which this species was obtained. (Type 1021.)

Genus CHÆNOMYA, MEEK.[1]

Synon.—*Mya* (sp.), PHILLIPS, Geol. York. I, 1835, 157 (not LINN.).
Panopæa (sp.), D'ORBIGNY, Prodr. de Palæont. I, 1850, 273.—MEEK & HAYDEN, Trans. Albany Inst. IV, March, 1858, 11 (not MENARD).
Myacites (sp.), MORRIS & LYCETT, Moll. Great Oolite, 1853, 114 (not SCHLOT.; MUNSTER).
Allorisma? (sp.), SWALLOW, Trans. St. Louis Acad. I, 1858, 194.—MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 263 (not KING, 1844).
Etym.—χαίνω, to open or gap; and *Mya.*
Type.—*Allorisma? leavenworthensis*, MEEK & HAYDEN.

Shell thin, equivalve, longitudinally oblong, subcylindrical. Anterior side rounded, closed; posterior side long, distinctly truncated, and very widely gaping, or even dilated at the extremity. Beaks depressed and located in advance of the middle. Surface minutely granulose, and usually provided with obscure concentric undulations, and more or less distinct lines of growth. Cardinal margins more or less inflected, as in *Allorisma;* ligament apparently entirely external; hinge edentulous. Posterior muscular impressions placed near the posterior extremity of the dorsal margin; scars of the anterior adductor and pedal muscles connected. Pallial line with a broad shallow sinus.

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[1] Since this description was placed in the hands of the printer, we have been led to suspect, from some incidental allusions to the genus *Anthracomya,* in a lecture by Prof. Salter, published in the London Geologist, that the group here described may possibly be identical with that genus. As we have not yet seen the description of *Anthracomya,* however (the Memoir in which it was published not being in the Smithsonian Library, nor any of those at Cambridge, New Haven or Philadelphia), we are left in doubt, and have concluded we would probably be less liable to err by proposing a new genus, than by referring our shells to *Anthracomya.* Should they prove to belong to Mr. Salter's genus, however, we will cheerfully accept for them, the names *Anthracomya leavenworthensis, A. Cooperi,* and *A. minnehaha.*

This genus seems to be closely allied to some of the species included by Prof. Agassiz in his genus *Platymya*—particularly to his *P. tenuis.* It differs, however, from *P. dilatata*, the type of the genus *Platymya*, in being subcylindrical instead of compressed, and in having the posterior side distinctly truncated and very widely gaping. Again it differs in having the surface covered with minute granules—a character not observed in any of the species referred to the genus *Platymya.* Prof. Agassiz, to whom we showed our specimens, concurs with us in the opinion that they are not congeneric with the forms upon which he founded his genus.

From *Allorisma* of King, and *Pleuromya*, Agassiz, as well as the typical species of *Myacites*, the species included in this group may be at once distinguished, by their truncated and widely gaping posterior end, and less prominent antero-ventral region, as well as by the more elevated position of the scar of the anterior muscular impression. All the species yet known are also destitute of any traces of a shallow depression extending from the beaks to the antero-ventral margin, so commonly seen in *Myacites*, while they want the cardinal teeth generally present in that genus. Again, they seem to have differed in their habits from the species generally placed in *Allorisma*, which were probably, as suggested by Prof. King, surface-creeping mollusks. At any rate, we observed in numerous instances while in Kansas, where specimens of *Allorisma* were to be seen side by side in the same bed with the typical species of the group under consideration, that the latter were, in nearly every instance, found imbedded at right angles to the plane of the strata, with the open posterior extremity upwards, as if in their normal position as burrowing shells; while the Allorismas were generally found lying in a horizontal position.

From the genus *Panopæa*, which our Kansas shells closely resemble in form, they differ in their greater thinness, faintly marked pallial line, granular surface, and entirely edentulous hinge.

This genus, as here defined, commences in the Coal Measures, and ranges up at least into the Great Oolite, if not higher. It includes *Chænomya dilatata* (= *Mya dilatata*, of Phillips), and probably several other Jurassic species; also our *Panopæa Cooperi*, and *Chænomya Minnehaha* (= *Allorisma? Minnehaha*, of Swallow), from the Upper Coal Measures of Kansas.

Chænomya leavenworthensis.

(Plate II, Fig. 1, *a*, *b*, *c*.)

Allorisma? leavenworthensis, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 263.

Shell oblong subcylindrical; anterior side rounded, a little compressed and apparently entirely closed; posterior side long, truncated, and very widely gaping, the margins being even a little reflexed. Base nearly straight, or slightly convex in outline, rounding up gradually in front, and very abruptly behind; dorsal side concave in outline from the beaks to its elevated posterior extremity, and nearly parallel to the base. Beaks rather depressed, somewhat flattened, incurved, nearly or quite touching, and located about half way between the middle and the anterior end. Surface marked by fine lines of growth, and a few irregular, nearly obsolete concentric undulations, which curve up abruptly behind, parallel to the truncated posterior margin; crossing these, the radiating rows of minute granules may be seen by the aid of a good lens, on well preserved specimens.

Internal casts of this species show quite distinctly the scar of the anterior adductor muscle, which is oval, and located near the buccal margin, with its longer axis nearly at right angles to that of the shell. At its upper extremity the small oval pedal scar is also well defined in both valves. The posterior muscular impression is broad oval, and rather faintly marked; from near the middle of its under side the pallial line descends with a gentle forward curve, so as to form a broad, rounded, very shallow sinus.

Length, 2.85 inches; height, from the ventral margin to middle of the dorsal side, 1.36 inch; do., from the base to a line drawn from the beaks across to the most elevated part of the posterior extremity, 1.50 inch; greatest convexity near the middle, 1.11 inch; breadth of posterior hiatus, 1.07 inch; height of do., 1.44 inch.

This species is so nearly like *Mya dilatata*, Phillips (as figured by Morris & Lyatt, Moll. Gt. Ool. vol. X, fig. 5), from the English Oolite, that if found imbedded with it in the same rock, they might, on a hasty examination, be mistaken for varieties of the same shell. On comparison, however, it will be seen that the Kansas species has its beaks more elevated, and placed nearer the anterior end; it is also a little broader shell, in proportion to its length, and rather straighter on the dorsal and ventral margins.

Locality and position.—Near the level of the Missouri River, at Leavenworth City, Kansas. Coal Measures. (Type 1019.)

Chænomya Cooperi.

(Plate II, Fig. 2, *a*, *b*.)

Panopæa Cooperi, Meek & Hayden, Trans. Albany Inst. IV, March 2d, 1858, 11.
Allorisma? Cooperi, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 264.

Shell oblong subcylindrical; posterior side very abruptly truncated, a little oblique, and widely gaping; anterior side more compressed, and rather narrowly rounded. Base nearly straight along the middle and behind, rounding up in front; dorsal side concave, and not declining behind the beaks, sloping rather abruptly in front. Beaks depressed, incurved, contiguous, and located about half way between the middle and the anterior end. Inflected cardinal margins a little thickened within, so as to leave a deep narrow depression along the cardinal border, in casts of the interior. Surface (of internal casts) marked by small, rather obscure concentric ridges, which are most distinct and regular on the umbones, and gradually fade away on other parts of the shell. (Muscular and pallial impressions unknown.)

Length, 2.57 inches; height, 1.37 inch; convexity or breadth, 1.12 inch; breadth of posterior hiatus, 1 inch.

This species will be readily distinguished from the last, by its proportionally shorter form, and more distinctly truncated and shorter posterior side. Its beaks are also rather less prominent, and marked by finer and more distinct concentric ridges. It seems to be more nearly related to a species described from the Coal Measures of Kansas, by Prof. Swallow, under the name of *Allorisma? minnehaha*, though our specimen wants the oblique ridge mentioned in the description of that species. Should they prove identical, however, the specific name *Cooperi* will have to take precedence, as it was published nearly a month in advance of the issue of Prof. Swallow's description.

Locality and position.—Helena, Kansas Territory. Coal Measures. (Type 1018.)

Class **GASTEROPODA.**

Sub-Class PROSOBRANCHIATA.

Order **Riphidoglossata.**

Sub-Order PODOPTHALMA.

Family PLEUROTOMARIIDÆ.

Shell varying in form, thickness and ornamentation, according to the genera and species; imperforate or more or less widely umbilicate, pearly within. Aperture not sinuous, or produced below. Outer lip with a more or less deep marginal slit or sinus near the middle, at the termination of a revolving band usually seen on all the whorls; sinus sometimes closed, excepting at intervals, so as to leave a series of isolated openings in the revolving band.

The animal of the typical genus (*Pleurotomaria*) of this extensive and interesting family, now so nearly extinct, has not, we believe, been described. That of *Scissurella*, however, an existing genus apparently related to this family (though its shell is not pearly within), has been studied by Mr. Lucas Barrett, who describes it as follows: "Tentacles long, serrate, at the base of which are placed the eyes; foot furnished with two pointed lappets, and two long, slender, serrated cirrhi on each side. Operculum very thin, ovate, with an obscure, subspiral nucleus. No part of the animal was external to the shell. The only living specimen occurred at Hammerfest, in forty-six fathoms of water."

The family *Pleurotomariidæ* was represented during the Palæozoic and several later epochs, by a great number of beautiful shells, presenting elegantly sculptured surfaces. It seems to stand, as it were, between the *Trochidæ* and the *Haliotidæ*, though authors are not agreed in regard to its relations to these and some of the allied groups. It includes the genera *Pleurotomaria*, *Platyschisma*, *Scissurella?* *Murchisonia*, *Trochotoma*, and *Polytremaria*. The Palæozoic groups *Euomphalus* (as typified by such forms as *E. pentangulatus*, Sowerby), *Scalites*, *Raphistoma*, *Helicotoma*, and some undescribed genera from the older rocks, seem also to be related to this family.

Genus PLEUROTOMARIA, Defrance.

Synon.—*Anatomus* [??], Montfort, Conch. Syst. II, 1810, p. 278.
Pleurotomaria, Defrance, Dict. Sci. Nat. XLI, 1826, 381.—Menke, Synon. 1828; and ib. 1830, 55.—Deshayes, Encyc. Meth. III, tab. 1830; and ib. 1832; 789.
Etym.—πλευρα, side; τεμνω, to cut.
Examp.—*Pleurotomaria Quoyana*, Fischer.

Shell trochiform, or more or less conical, pearly within, and variable in thickness according to the species, with or without an umbilicus; volutions angular, flattened or rounded. Surface variously ornamented with striæ, nodes, granulations or carinæ. Aperture subquadrate, semi-oval, suborbicular or subrhombic; inner lip usually thin; fissure of outer lip generally narrow and deep; revolving band corresponding in breadth with the sinus.

The shells included in this genus are very similar in form, and the possession of a fissured lip, to those of the recent genus *Scissurella*, but differ in size and texture—all the known species of *Scissurella* being minute, non-perlaceous shells. The Pleurotomarias also closely resemble the genus *Anatomus*, of Montfort, from which Hermannsen and some others think they are not distinct. Other authors regard *Scissurella*, D'Orbigny, and *Anatomus*, of Montfort, as synonymous. Judging from Montfort's description of the genus *Anatomus*, however, it seems scarcely possible that it can be identical with *Scissurella*, since he distinctly states that the typical species of his genus is a pearly shell, and that the animal is without eyes. From all the facts, it seems to be much more probable that *Anatomus* and *Pleurotomaria* are identical, than that either belong to the same genus as *Scissurella.* If they are synonymous, of course Montfort's name *Anatomus* must be adopted, since it has priority of date. Until their identity is more satisfactorily determined, however, we prefer to retain the name *Pleurotomaria.*

The founder of this genus divided it into two sections, one including the umbilicated species, with a rounded aperture, and the other those without an umbilicus. These sections have been regarded by other authors as distinct genera, but there are so many intermediate gradations connecting the umbilicate and imperforate species, that it is scarcely possible this can be regarded as a generic character. It is quite probable, however, that distinct genera have been confounded under the name *Pleurotomaria*, amongst the fossil species.[1]

The genus *Pleurotomaria* was introduced at an early period, a number of species having been described from the Lower Silurian Rocks. It is also represented through the succeeding formations, and is particularly abundant in the Coal Measures of the Western States. It attained its greatest numerical development during the Jurassic epoch, and is well represented in the Cretaceous strata; since the deposition of which it has rapidly declined. At present but two living species are known, one of which occurs on the coast of Marie Galante, and the habitat of the other is unknown. Both of these species are very similar to some of those found in the Jurassic and Cretaceous rocks. The Palæozoic species, as might be expected, retain no traces of their original pearly lustre, though some of those found in the more modern rocks are still nacreous.

Pleurotomaria humerosa.

(Plate I, Fig. 14, *a*, *b*.)

Pleurotomaria humerosa, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 262.

Shell turbinate, or conical subovate; spire turreted, moderately elevated. Volutions five to five and a half, very convex, more or less obliquely flattened above, rounded below, and distinctly angular at the outer margin of the flattened upper side. Suture distinct; columella with a small shallow umbilical perforation. Surface ornamented by about ten rather strong revolving lines, only some three or four of which are visible on the upper whorls below the angle; on the flattened upper surface of the whorls there are five to seven additional, much smaller revolving striæ, sometimes obsolete on worn specimens. Aperture suborbicular.

Length, 0.62 inch; breadth, 0.50 inch; apical angle about 62°.

None of the specimens of this species we have seen have the lip entire, and as the lines of growth are not preserved, it is impossible to determine the nature and position of the labial sinus and spiral band. From analogy, however, we would suppose the band to occupy a position just outside of the angle of the shoulder, and of course the sinus of the lip, in that case, would be near the point where it is intersected by this angle.

This shell seems to be rather closely allied to *Pleurotomaria Yranii*, Leveille

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[1] Hermannsen places *Ptychomphalus*, Agassiz (Germ. Trans. Sowerby's Min. Conch. 1837, 23, 222, 310), as a synonym of *Pleurotomaria.* We are not well enough acquainted, however, with the type of Prof. Agassiz's genus (*Helicina compressa*, of Sowerby, from the Lias), which we only know from an examination of Sowerby's imperfect figures, to express an opinion in regard to its relations.

(sp.), as figured by Koninck, on pl. 37 of his work on the Carboniferous Fossils of Belgium. It is considerably smaller, however, has one or two whorls less, and proportionally larger, and less numerous revolving lines below the shoulder; while those above are smaller in proportion to the breadth of the flattened upper side. It is also related to *P. subsinuata*, of Meek & Worthen (Proc. Acad. Nat. Sci. Phila. Oct. 1860), but has a more elevated spire, while the upper side of its whorls are more distinctly flattened, and shouldered.

Locality and position.—Grasshopper Creek, Northeastern Kansas. Coal Measures. (Type 1002.)

Pleurotomaria subturbinata.

(Plate I, Fig. 13.)

Pleurotomaria subturbinata, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 264.

Shell small, comparatively thick, obliquely conical; spire moderately elevated, rather pointed at the apex. Volutions six to six and a half, convex, and angular in the middle, obliquely concave above, and having around the middle of the last, just below the angle, a rather narrow, shallow, revolving sulcus. Umbilical region a little depressed, and perforated by a very small pit; aperture suborbicular. Surface ornamented by small revolving lines (only preserved on the under and outer sides of the body whorl, in our specimen, which is somewhat worn and shows no lines of growth). Angle on the middle of the whorls apparently double, or composed of two parallel lines.

Length, 0.36 inch; breadth, 0.29 inch; spiral angle regular, divergence 69°.

We have seen no specimens of this species with the lip in a condition to show the nature and position of the sinus; nor are the lines of growth sufficiently well preserved to indicate the position of the spiral band. It is probable, however, from the appearance of the specimens, that the band is coincident with the sulcus below the angle on the middle of the body whorl.

Locality and position same as last. (Type 1003.)

CARBONIFEROUS AGE.

(PERMIAN PERIOD.)

MOLLUSCA.

CLASS **LAMELLIBRANCHIATA.**

FAMILY PECTINIDÆ.

Shell suborbicular, inequivalve, nearly or quite equilateral, very slightly oblique, and more or less distinctly auriculate; not nacreous, and without a prismatic structure. Hinge line straight; ligament marginal. Cartilage generally confined to an internal pit or groove under the beaks; sometimes occupying linear furrows in a cardinal area. Anterior margin of one valve more or less deeply notched, or sinuous, for the passage of the foot or byssus. Scar of the adductor muscle large, and subcentral; pallial line simple.

Animal with mantle freely open and provided with double margins, the inner one of which is fringed with pendent filaments, and the outer bounded by a row of distinct ocular dots, or rudimentary eyes. Palpi smooth externally, and pectinated on their inner sides; mouth surrounded by foliaceous leaflets. Gills equal, each pair partially folded upon itself. Foot small, cylindrical, grooved, forming a byssus while the animal is young. Sexes united.

The *Pectinidæ* are closely related to the *Spondylidæ*, which form a natural transition to the *Ostreidæ*. They differ, however, in the more regular form of the shell, and in never being attached by the substance of the valves. They also generally want the strong interlocking teeth of the typical *Spondylidæ*, and the animal differs in having a more developed foot and numerous ocular dots.

In order to include in this family some extinct forms apparently belonging here, it seems to be necessary to admit at least two distinct sub-families, distinguished as below:—

1. Pectininæ.

Shell with anterior ear usually a little larger than the other; cartilage occupying an internal pit or groove under the beaks.

Includes the genera *Pecten*, *Vola*, *Camptonectes*, *Amussium*, *Syncyclonema*, *Hemipecten*, and many undescribed living and extinct genera.[1]

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[1] We have been informed by Prof. Agassiz that he has recently studied this family with much care, and that he finds it necessary to establish numerous new genera, which he has not yet published, making, with those already established, more than fifty distinct genera, living and extinct.

2. Aviculo-pectininæ.

Shell with posterior ear generally larger than the other; hinge without a central cartilage pit; cartilage apparently occupying a series of linear furrows in a more or less broad cardinal area.

Includes *Aviculopecten*, *Streblopteria*, and probably several undefined Palæozoic genera.

The *Aviculopecten* group seems to form a kind of transition from the *Pectinidæ* to the *Pteriidæ*, and may possibly be distinct from them both, though it is evidently more closely allied to the former than the latter. It seems to bear much the same relations to the typical forms of the *Pectinidæ* that the *Pteriniinæ* do to the typical *Pteriidæ*.

SUBFAMILY AVICULOPECTININÆ.

Genus AVICULOPECTEN, McCoy.

Synon.—*Avicula*, *Pecten*, and *Meleagrina* (sp.), of various authors.
Aviculopecten, McCoy, Ann. Mag. Nat. Hist. VII, 1851, 171; Brit. Pal. Foss. 1852, 392.
Etym.—*Avicula* and *Pecten*.
Examp.—*Aviculopecten docens*, McCoy.[1]

Animal unknown. Shell inequivalve, more or less inequilateral; straight, or slightly extended obliquely towards the posterior side; anterior ear flattened, smaller than the posterior, sharply and deeply defined, with a notch in the right valve between it and the body of the shell for the passage of the byssus;[2] posterior ear pointed, extending about as far as the margin of the shell, defined or not; ligament confined to a narrow[3] facet along the hinge margin; no medial cartilage pit; muscular impression and pallial scar as in *Pecten*. (McCoy.)

We entirely concur with Prof. McCoy in separating this group of shells both from *Pteria* (= *Avicula*) and *Pecten*. From the typical species of the latter of these genera, they differ materially in having the cartilage extended along the hinge instead of occupying a mesial pit under the beaks; they also present the external difference of having the posterior ear larger than the other. From the Pterias they are clearly separated by their more equilateral and less oblique form, edentulous hinge, and the arrangement of the cartilage, as well as by their shell structure.

Some difference of opinion exists in regard to the family relations of this genus, several authors placing it in the *Aviculidæ*, and others with the *Pectinidæ*. We

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[1] In first proposing this genus in the Annals and Mag. Nat. Hist. (VII, 1851, p. 171), Prof. McCoy does not say what species he regards as the type, though he figures, as an illustration of the genus, a species (without a name), which seems to be his *A. docens;* at any rate it is clearly congeneric with that form.

[2] Judging from Prof. McCoy's figures of Palæozoic *Pectinidæ*, in his Synopsis of the Carboniferous Fossils of Ireland, the byssal sinus would seem to be sometimes as strongly defined under the anterior ear of the *right*, as well as the *left* valve, in *Aviculopecten;* or there is another genus presenting that character.

[3] Some of our American species have a broad cardinal area, marked with distinct cartilage furrows ranging parallel to the hinge line, or sometimes divaricately deflected under the beaks.

are decidedly of the opinion, however, that it is more nearly allied to the latter. It is true these shells have no internal cartilage pit, but we have ascertained that they have the shell structure of the *Pectinidæ*, and not that of the *Pteriidæ*.

The annexed cut shows the structure of *Aviculopecten amplus*, Meek & Worthen, as seen in a fragment placed in Canada balsam, under a magnifier of 350 diameters.[1]

It will be seen that there is here no traces of the prismatic cellular structure of the *Pteriidæ*. The shell, on the contrary, is composed of very thin laminæ, with striated or corrugated surfaces as in the *Pectinidæ*. These striæ are not parallel on the different laminæ, nor on the opposite sides of the same layer, but arranged so that on looking through several of these plates they are seen crossing each other at various angles. From this structure, therefore, taken in connection with the form and general appearance of these shells, it is manifest they belong to the *Pectinidæ*, or possibly to an intermediate group between that and the *Pteriidæ*.

This genus was probably introduced during the deposition of the Devonian rocks. It attained its maximum development during the Carboniferous epoch, and is also represented in the Permian rocks, the deposition of which it seems not to have survived.

Aviculopecten ——————?

(Plate II, Fig. 10.)

Comp. *Pecten cleavelandicus*, Swallow, Trans. Acad. St. Louis, I, Feb. 22, 1858, p. 182.

We are in doubt whether or not this shell is identical with Prof. Swallow's species cited above, and consequently prefer not to describe it as new, though we suspect it may prove to be distinct. It certainly does not appear to have presented the same proportions, judging from his measurements, which make the height and breadth of his species as 1.63 to 0.95; though we think there must be a typographical error in these figures, since *P. cleavelandicus* is described as being "orbicular." It would also seem to differ from our shell in being "oblique."

Locality and position.—Kansas; near Chapman's Creek, eighteen miles above Fort Riley. Permian beds.

Aviculopecten McCoyi.

(Plate II, Fig. 9.)

Shell under medium size, broad subovate exclusive of the ears; not oblique, rounded on the ventral margin, and having a moderately deep, rounded sinus under each ear. Hinge margin sloping slightly from the beaks, and equalling about three-fourths the breadth of the widest part of the valves below. Left valve gibbous; umbo convex, its sides converging at an angle of about 85° to the apex; ears nearly equal, the posterior one being a little larger and more angular than the other. Anterior ear somewhat rounded at the extremity, separated from the swell of

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[1] The lines are too straight and regular in this cut. Wood engraving is not well adapted to the illustration of such objects.

the umbo by an oblique, rather deep, rounded depression. Surface ornamented by simple, rounded, unequal radiating costæ, which are crossed by exceedingly fine, regular, closely-arranged concentric striæ, and a few stronger marks of growth.

Of the sixty or seventy radiating costæ seen on the left valve, some nine or ten occupy each ear—those on the anterior ear being a little coarser and more distinct than on the other. On the body part of the valve, about every fourth or sixth one of the costæ is a little larger than the others, and provided with a few distant, rather regularly disposed, vaulted, scale-like projections, which may, on well-preserved specimens, sometimes assume the character of short spines. Only the largest costæ extend quite to the apex of the beak, while another series nearly reaches it; a third series dies out from one-half to two-thirds of the way up from the border, and a fourth extends generally less than half way up.

Height, from the ventral margin to the hinge, 0.83 inch; breadth, or greatest transverse diameter, 0.75 inch; breadth of narrowest part just under the ears, 0.45 inch; length of hinge, 0.49 inch; convexity (of left valve), 0.22 inch.

This species may be distinguished from any of those resembling it in other respects, yet known to us from these rocks, by the rugose or subspinous character of its largest costæ, and its fine concentric striæ. It bears some resemblance to *A. segregatus*, McCoy (British Pal. Foss. pl. 3, E, fig. 1), but is a proportionally narrower shell, has a shorter hinge, and more slender costæ. It also probably differs in the possession of the fine concentric lines mentioned above, though Prof. McCoy's specimen was apparently not in a condition to have retained these, if it ever possessed them.

Named in honor of Prof. Frederic McCoy, of Dublin, Ireland, the author of the genus.

Locality and position.—South Cotton-Wood Creek, Kansas. Permian beds.

FAMILY PTERIIDÆ. (See page 27.)

SUBFAMILY PTERINIINÆ. (See page 28.)

Genus MYALINA, KONINCK. (See page 30.)

Myalina aviculoides.

(PLATE II, Fig. 8, *a*, *b*, *c*, *d*.)

Myalina aviculoides, MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. May, 1860, p. 184.

Shell subtrigonal, higher than long, very convex, or subangular down the umbonal slopes; anterior margin distinctly sinuous above the middle, thence descending with a slightly convex curve, nearly at right angles with the hinge to the basal extremity, which is narrowly rounded. Posterior side compressed, its margin curving a little forward above, or intersecting the hinge at right angles; slightly convex and nearly perpendicular along the middle, below which it curves obliquely forward to the abruptly rounded basal extremity. Hinge straight, nearly equalling the length of the shell; beaks very convex, subangular, and curving rather abruptly forward, so as to become nearly or quite terminal. Surface having moderately distinct concentric marks of growth.

Length, 1.48 inch; height, 1.66 inch; convexity of a left valve, 0.32 inch.

This form may be readily distinguished from all the other species of the genus known to us, resembling it in other respects, by its peculiar sinuous, or arcuate front, and the extended or somewhat lobed character of its anterior margin under the beaks. Young or undeveloped individuals are generally longer than high, and have much more oblique umbonal slopes than adults. As the shell advanced in size, however, the umbonal ridges curved down so as to stand nearly at right angles to the hinge, and the valves became elongated in the same direction, so as to make the height greater than the length. Usually the anterior margins of the valves below the most sinuous part are deflected from the umbonal slopes rather abruptly inwards, so as to meet at an obtuse angle, or sometimes almost on the same plane.

Locality and position.—Cotton-Wood Creek, Kansas, south of Kansas River. Permian beds. (Type 3961.)

Myalina permiana.

(PLATE II, Fig. 7, *a*, *b*, *c*.)

Mytilus (*Myalina*) *permianus*, SWALLOW, Trans. St. Louis Acad. Sci. Vol. I, March 8, 1858, 17.
Mytilus (*Myalina?*) *concavus*, SWALLOW, ib. 18.

Shell obliquely subovate, or subtrigonal; convex anteriorly, and cuneate behind; beaks terminal, rather pointed, and directed nearly horizontally forward at the points. Umbonal slopes prominent from the beaks down along the front of the valves. Hinge straight, generally more than equalling half the greatest length of the shell, and ranging at an angle of 60° to 65° with the oblique anterior margin; cardinal area of moderate breadth, and distinctly striate. Posterior margin rounding down with a broad sweep from the posterior extremity of the hinge, to the abruptly rounded antero-ventral extremity; anterior margin concave, or more or less arcuate in outline from the beaks to the base, and very abruptly inflected from the prominent umbonal ridge of each valve. Surface marked by obscure concentric striæ, or nearly smooth.

Length, from the beaks to the antero-basal extremity, 1.75 inch; length of hinge, 1.08 inch; breadth, 0.96 inch; convexity, about 0.70.

Prof. Swallow's descriptions of the two forms cited above, agree so nearly with the specimens before us, that we can scarcely entertain a doubt in regard to their identity, especially when we bear in mind that they came from the same beds, at near the same locality. Our specimens also show various gradations between the shorter and more elongate forms, so that we cannot believe a specific distinction can be based upon these differences.

This species is evidently very closely allied to a shell described by Dr. Isaac Lea, of Philadelphia, from the Coal Measures of Pennsylvania, under the name of *Modiola wyomingensis* (Jour. Acad. Nat. Sci. Phila. vol. II, 2d ser. p. 205, pl. xx, fig. 1). Dr. Lea's figure seems to represent a slightly more oblique shell, with a little longer hinge; but as the species before us is variable in these characters, we are prepared to believe the Kansas and Pennsylvania shells may possibly prove to belong to the same species. If so, Dr. Lea's specific name will have to be adopted, since his paper was published in 1852.

The species under description may be distinguished from our *M. perattenuata*, by its more robust appearance, broader form, and less attenuate beaks. It is probably also a thicker shell than *M. perattenuata*, though our specimens being all cast, we are not sure this is the case.

Locality and position.—From Permian beds near the Smoky Hill fork of Kansas River; on Cotton-Wood Creek, and at many other localities south of Kansas and Smoky Hill River, in northeastern Kansas. We think we have also seen it in the Coal Measures below, in the same region. (Type 1153.)

SUBFAMILY PTERIINÆ. (See page 28.)

Genus EUMICROTIS, MEEK.

Synon.—*Gryphites* (sp.), SCHLOT. Acad. Munch. 1816, 30; ib. Petref. 1820, 292.
Avicula (sp.), J. DE C. SOWERBY, Trans. Geol. Soc. Lond. 2d ser. III, 1829, 119, and of various others (not KLEIN; LAMK.).
Monotis, KING, Catalogue Perm. Foss. 1849, p. 9; id. Monogr. Perm. Foss. Great Brit. 1850, p. 154.—MEEK & HAYDEN, Trans. Albany Inst. IV, March 2d, 1858.—SWALLOW, Trans. St. Louis Acad. Sci. I, 1858.—SHUMARD, ib. 1859 (not BRONN, 1830).
Eumicrotis, MEEK, American Jour. Sci. 2d ser. XXXVII, March, 1864, p. 216.
Etym.—ευ, very; μικρός, small; οὖς, ear.
Type.—*Monotis Hawni*, MEEK & HAYDEN.

Shell suborbicular, plano-convex, the left valve being usually very convex, and the right flat, or even a little concave; not distinctly auriculate, the ears being nearly obsolete. Beaks sub-central, very slightly oblique, unequal, that of the left valve often elevated, gibbous and incurved; the other very small, and scarcely projecting above the hinge line. Hinge short, narrow, edentulous; cartilage cavity under the beaks (King). Byssal notch or sinus of right valve narrow, deep, and separated from the hinge by a very small rudimentary ear, which does not project beyond the margin. Adductor muscular scar large and sub-central, impressions of retractor muscles several, small and placed near the beaks. Surface generally with radiating, more or less vaulted or scaly costæ, much more distinctly marked on the left than the right valve.

The shells embraced in this genus are apparently most nearly allied to *Aucella* of Keyserling, to which Prof. McCoy refers them. Although Count Keyserling's genus has not been generally adopted, it seems to be entirely distinct from all the allied groups, and has been clearly defined by its distinguished author. All the species upon which it was founded, however, differ from those of the group under consideration, in being much more oblique, more oval in form, and entirely destitute of any traces of radiating costæ or striæ; while they are all marked with more or less distinct and regular concentric costæ or undulations, as in *Inoceramus.* Again, they have the right or smaller valve proportionally more ventricose than in *Eumicrotis*, and also possess a minute, internally concave, sharply defined anterior ear under the beak of the left valve, never seen in the group we are describing. Another difference is the entire absence of the lobed appearance of the posterior side of the valves in *Aucella*, so often seen in the typical forms of *Eumicrotis.* In addition to these differences, Count Keyserling's figures (*Petschora Land*, tab. 16) show that in the type of his genus the scar of the adductor muscle is nearly marginal; and that there is no distinct cartilage cavity under the beaks; while according to Prof. King, there is in *E. speluncaria*, Schlot. (sp.).

That the group of shells we are describing are not congeneric with *Monotis* of Bronn, must be manifest to any one who will take the trouble to compare one of these forms with *Monotis salinaria*, the type of Bronn's genus. This shell, it will be observed, differs from all of those included in the genus *Eumicrotis*, in being more oval in outline, more compressed, more oblique, and very nearly if not quite equivalve; while very little difference can be seen between the prominence of its right and left beaks. Its most important peculiarity, however, is the total absence of any traces of a byssal notch or sinus in the anterior margin of either valve.

The typical forms of the genus *Eumicrotis* are, so far as known, confined to the Permian rocks in Europe, and to the Permian and upper Carboniferous of America. In addition to the type—*E. Hawni*, M. & H.—this genus includes *E. speluncaria*, Schlot. (sp.), *E. radiatus*, Phillips (sp.), *E. Garforthensis*, King (sp.); and *E. Halli* and *E. variabilis*, Swallow (sp.).[1]

A small section of this group, of which *Avicula substriata* of Munster is an example, seems to be mainly confined to the Jurassic rocks, though it may also be represented in the Trias. These shells should probably rank as a distinct subgenus, though with our present means of comparison we are not fully satisfied that this is the case.

Some Palæontologists will insist upon referring to the genus *Pteria* (*Avicula*), all such forms as those included in the groups above characterized. A moment's comparison, however, of these shells with the recent typical forms of that genus, can scarcely fail to convince any skilful Conchologist that such a mingling of types is totally inadmissible in our present advanced state of Natural History.

Eumicrotis Hawni.

(PLATE II, Fig. 5, *a*, *b*, *c*.)

Monotis Hawni, MEEK & HAYDEN, Trans. Albany Inst. IV, March 2d, 1858.
Monotis speluncaria, var. *americana*, SWALLOW, Trans. St. Louis Acad. Sci. I, 184.
Monotus speluncaria, Shumard ? 1859, Trans. St. Louis Acad. Sci. I, 396 (non SCHLOT.).
Eumicrotis Hawni, (M. & H.) MEEK, Am. Jour. Sci. XXXVII, March, 1864, 216.

Shell subcircular, or subovate; hinge straight, equalling about half the length of the valves; beaks sub-central, short, not oblique; ears nearly obsolete; base rounded, antero-ventral and postero-ventral margins rounded, the

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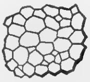
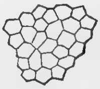
[1] Prof. King suggests that the genus including *E. speluncaria* probably belongs more properly to the *Pectenidæ* than to the *Aviculidæ*, since Mr. Carpenter had found that *Avicula cygnipes* of Phillips, supposed to be congeneric with *E. speluncaria*, presents the microscopic structure of the *Pectenidæ*, and not that of the *Pteriidæ*. We think, however, that it is very improbable that these two shells can be congeneric, for we find our *E. Hawni*, which is even specifically very closely allied to, and certainly congeneric with, *E. speluncaria*, shows very distinctly, under a high magnifying power, the prismatic structure of the *Pteriidæ*. The annexed cut, No. 1, represents the structure of this species as seen

No. 1.



Shell structure of *E. Hawni*.

No. 2.



Shell structure of *E. curta*.

by transmitted light, when magnified about 300 diameters. We also observed the same structure in the Jurassic species *Eumicrotis curta*, Hall (sp.), as may be seen by the annexed cut, No. 2.

In regard to the relations of *Avicula cygnipes*, of Phillips, to *Monotis salinaria*, Bronn, we would merely state that we differ widely from those who would place two such shells in the same genus.

latter being somewhat more prominent than the other. Left valve convex; anterior margin sometimes slightly sinuous near the hinge above; posterior margin intersecting the hinge at an obtuse angle; beak convex, extending but slightly beyond the hinge line. Right valve nearly or quite flat; beak flat, not projecting beyond the hinge; byssal sinus narrow, deep, or extending back parallel to the hinge to a point nearly under the beak.

Surface of both valves, particularly the left one, ornamented with more or less distinct radiating costæ, which are usually separated by spaces three or four times their own breadth, and armed with regularly disposed vaulted, spine-like prominences, formed apparently by the projecting laminæ of growth. Between each two of the principal costæ from one to three or four much smaller radiating ribs or lines are usually seen, crossed by obscure concentric markings. (Hinge and muscular impressions unknown.)

Length, 1.47 inch; height, 1.42 inch; convexity, about 0.40 inch.

In first describing this species, we called attention to its close relations to *E. speluncaria*, Schlot. (sp.), and stated that we were aware it would not be easy always to find characteristic differences by which certain varieties of these two forms could be distinguished. Every naturalist, however, must have met with analogous cases, where the varieties of two closely allied, but variable species approximate, and, as it were, mingle together, so as to render it sometimes extremely difficult to separate them; while the normal forms of each are so clearly distinct as to leave no doubt on the mind that they belong to different species. This, we think, is the relations the Kansas shells bear to *E. speluncaria*, although we are aware some of our friends entertain the opinion that they are not specifically distinct.

It is true, some specimens agree almost exactly with such varieties of *E. speluncaria* as are represented by figures 15, 17, 20 and 21, pl. xiii, of King's work on the Permian Fossils of England; yet out of hundreds of individuals, collected and seen by us in Kansas, we have never met with one presenting the peculiar lobed and sulcated posterior, so characteristic of the well developed normal forms of *E. speluncaria*, such, for instance, as figures 5, 6, 7, 8, 9, 10 and 11 of plate xiii, in King's work cited above. Again, none of our Kansas specimens, with a solitary exception, has the beak of the right valve so gibbous, or near so elevated, as those represented by the figures last above cited; and in this single exception, the shell differs so widely in other respects, that if not a monstrosity, we can but regard it as belonging to a distinct species from that under consideration, as well as from *E. speluncaria.*

Locality and position.—Near the mouth of Smoky Hill fork of Kansas River, and at several places on the high country between there and Council Grove, as well as on Cotton-Wood Creek, Kansas. Permian. (Type 3958.)

Eumicrotis Hawni, var. **ovata.**

(Plate II, Fig. 6, *a*, *b*.)

This variety differs from the typical forms of *M. Hawni*, in being more compressed, and more ovate in outline, its diameter from the hinge to the ventral margin being proportionally greater; while its hinge margin is much shorter, or not more than equalling about one-third, instead of one-half, the greatest breadth of the valves. Its costæ are also usually more distinctly defined, and its beak rather more pointed. In some respects it resembles *M. Garforthensis*, King, but its costæ are not so uniform, nor so spinous. We are inclined to think it will prove to be specifically distinct from *E. Hawni;* but as we are not clearly satisfied that this is the case, we merely name it for the present as a variety of that species.

Diameter, from hinge to ventral margin, 1.54 inch; breadth, 1.43 inch; convexity of left valve, 0.28 inch.

Locality and position.—Near Cotton-Wood Creek, south of the Santa Fé Road, Kansas. Permian. (Type 1157.)

SUBFAMILY MELININÆ. (See page 28.)

Genus BAKEVELLIA, KING.

Synon.—*Mytilites* (sp.), SCHLOT. Akad. Munch. VI, 1816, 30; ib. Petref. 1820, 293.
Avicula (sp.), J. DE C. SOWERBY, Trans. Geol. Soc. 2d ser. III, 1829, 119.—GOLDF. Petref. 2d part, 1826, 126, and of several others (not [KLEIN] LAMK.).
Bakevellia, KING, Catalogue, 1848, 10.
Gervillia, GEINITZ, Versteinerungen, 1848, 10; ib. Dyas, 1862 (not DEFRANCE, 1820).
Etym.—Dedicated to Robert Bakewell, of Hampstead, England.
Type.—*Avicula antiqua*, MUNSTER.

Shell more or less aviculiform, subequivalve; valves somewhat sinuous and a little gaping in front for the passage of the byssus. Umbones depressed and oblique. Surface with concentric striæ. Hinge provided with a few linear anterior and posterior lateral teeth, arranged nearly or quite parallel to the cardinal margin. Muscular scars much as in *Pteria* (*Avicula*), excepting that the anterior one is larger and more distinct. Cardinal area usually well developed in both valves; cartilage furrows distinct, two to five in each valve.

Animal unknown.

In form, as well as in the possession of a more or less developed anterior and posterior wing, and the inequality of the valves, the species of this genus are often very similar to *Pteria;* from which, however, they differ in the possession of a large, deeply grooved cardinal area, and a divided cartilage, as well as in the nature of the hinge teeth, and the proportionally larger size of the anterior muscular impression.

In the possession of a broad cardinal area, crossed by a few deep furrows for the reception of the cartilage, the Bakevellias seem to present affinities to the genus *Gervillia*, which some of the species closely resemble in form. The nature of the hinge, however, and the greater development of the anterior muscular scar, clearly separate them from that group, at least generically.

Prof. King, the able author of the excellent Monograph of the Permian Fossils of England, thinks the comparatively large size of the anterior muscular impression in this genus, sufficiently marked, not only to separate it from *Pteria*, but to remove it entirely from the *Pteriidæ*. Still in the rather low, or nearly sub-central position of the posterior muscular impression, when taken in connection with the general similarity of these shells to *Pteria* and *Gervillia*, they seem to present a combination of characters bringing them very near, if not within the *Pteriidæ*.

In Europe, the genus *Bakevellia* is generally regarded as being restricted to the Permian System. If the following described species, however, really belongs to this genus, it would seem to have been introduced at a somewhat earlier period here, since we have seen it in Kansas in beds we regard as probably of the age of the Coal Measures, though it ranges up, and is most abundant in the Permian beds above.

Bakevellia parva.

(PLATE II, Fig. 12, *a*, *b*.)

Bakevellia parva, MEEK & HAYDEN, Trans. Albany Inst. IV, March 2d, 1858.

Shell very small, obliquely subovate, oblong, or subrhombic in outline; valves gibbous along the oblique umbonal slopes. Antero-ventral margin sloping very obliquely backwards and downwards; rather distinctly sinuous under the beaks. Postero-basal extremity rounded; anal edge sinuous above; anterior extremity somewhat lobed, subangular or very narrowly rounded. Hinge line straight, nearly or quite equalling the greatest length of the shell, and ranging at an angle of about 35° to the umbonal prominences. Beaks rather small, rising a little above the hinge, incurved, and located about half way between the middle and the anterior extremity. Postero-dorsal region compressed, or more or less alate, and terminating at a distinct angle at the extremity of the hinge. Surface with concentric striæ. Anterior teeth of hinge, one or two to each valve, linear and declining a little in front; posterior teeth, one or two, long, linear and ranging parallel to the hinge margin.

Length, 0.20 inch; height, 0.10 inch; thickness or convexity of the valves, about 0.08 inch.

We can scarcely regard it as a clearly established fact that this little shell possesses all the characters of Prof. King's genus *Bakevellia*, since its cardinal area and muscular and pallial impressions have not yet been seen. It agrees, however, so exactly in form and general appearance, as well as in the nature and arrangement of its hinge teeth with that genus, and differs so materially in the latter character and the absence of a byssal sinus from *Pteria*, that we do not feel warranted in removing it from the genus in which we first provisionally placed it.

It agrees very nearly in form with some varieties of *Bakevellia antiqua*, Munster (sp.), but is uniformly much smaller—never being more than one-fourth the average size of that shell; while its cardinal area must be much narrower, judging from the close proximity of the beaks; the posterior extremity of its hinge is also much more angular.

Locality and position.—Near the mouth of Smoky Hill fork of Kansas River; on Cotton-Wood Creek, and at numerous other localities in northeastern Kansas; in beds of yellowish magnesian limestone of Permian Age. (Type 3959.)

FAMILY TRIGONIIDÆ.

Shell equivalve, generally inequilateral, closed, varying greatly in form and ornamentation, according to the several genera and smaller groups, nacreous within. Ligament external; hinge composed of a few diverging, usually large, interlocking teeth.

Animal with two recumbent gills on each side; palpi simple; mantle open; foot long, lanceolate, bent, and formed for leaping.

This family includes the following genera: *Schizodus*, *Myophoria*, *Trigonia*, and *Verticordia?* The first two of these genera are entirely extinct, while the Trigonias, which were most abundant during the Jurassic and Cretaceous epochs, are still represented by a few living species. Of the genus *Verticordia*, only one or two Tertiary species, and one living species are known.

In tracing the different groups of this family, from its first appearance in the Palæozoic rocks, as plain shells (*Schizodus*) with smooth weak hinge teeth, it is exceedingly interesting to see how gradually they shade off through the smooth, subplicate, and plicate Myophorias of the Trias, with their more developed hinge, into the highly ornate Jurassic, Cretaceous, and living Trigonias, with their still more complex dental system.

Genus SCHIZODUS, King.

Synon.—*Tellinites* (sp.), Schlot. Akad. Münch. VI, 1816, 31.
Axinus (*obscurus*), Sowerby, Min. Con. IV, 1821, 12.
Isocardia (*axiniformis*), Phillips, Geol. York. 1836, 209.
Cucullæa (*Schlotheimi*), Geinitz, Neues Jahrb. 1841, 638.
Donax? (*sulcatus*), J. de C. Sowerby, Geol. Tr. V, 1840, 491.
Sedgwickia (*gigantea*), McCoy? Carb. Foss. Ireland, 1844, 62.
Dolabra[1] (part), McCoy, Carb. Foss. Ireland, 1844, 64.
Myophoria, McCoy, 1855, Palæozoic Foss. Great Brit. 1855, 494 (not Bronn, 1855).
Schizodus, King, Ann. Mag. Nat. Hist. XIV, 1844, 313.
Etym.—σχιξω, I split; οδους, a tooth.
Type.—*Schizodus truncatus*, King.

Shell more or less oval or subtrigonal; anterior side rounded and shorter than the other; posterior side tapering, more or less truncate at the extremity, and usually having an umbonal ridge extending from the beaks to the postero-basal margin. Beaks generally prominent. Surface smooth, or ornamented with concentric striæ. Hinge with two smooth cardinal teeth in the right valve, and three in the left; the middle tooth of the left valve being more or less bifid, and fitting between the two of the opposite valve. Free margins smooth.

Animal unknown.

As pointed out by Prof. King, this genus is closely related to *Myophoria*, of Bronn. Prof. McCoy has also subsequently expressed the opinion that the slight differences observable between the teeth of the hinge in these two groups are not of generic value, and ranges the species under Bronn's name *Myophoria*.[2] As we have had no opportunity to examine specimens showing the hinge, we merely retain provisionally, the name proposed by Prof. King. We would remark, however, that so far as we can judge from figures alone, we are inclined to think that the non-plicated Carboniferous and Permian species, with possibly a few of the similar forms from the Triassic rocks, should be retained under Prof. King's name, either as a distinct genus, or as a subgenus under *Myophoria*.

Prof. King has also called attention to the close relations between these two groups and the genus *Trigonia;* the principal difference between them, so far as the hinge is concerned, being the greater development, and sulcated character of

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[1] As proposed by McCoy, the genus *Dolabra* was made to include species belonging to two distinct families. The first or typical species, *Cucullæa angusta*, Sw., and three others included by McCoy, constitute the genus *Dolabra* as properly restricted, by the separation of the species upon which Prof. King founded the genus *Schizodus*. As thus restricted, the genus *Dolabra* belongs to the *Arcidæ*, and seems to be closely allied to *Cucullæa*, Lamk. *Dolabra? alpina*, Hall, Iowa Report, I, part 2, p. 716, pl. xxix, fig. 2, is a true *Schizodus*, and its name should be *Schizodus alpinus*.

[2] British Pal. Foss. p. 494.

the teeth in the latter group. Externally, the differences between the Trigonias, and the plicated, or costated species of *Myophoria*, are about as great as those between the latter and the smooth typical species of *Schizodus.*

The genus *Schizodus*, as above defined, was probably introduced during the deposition of the Upper Silurian rocks.[1] It also occurs in the Devonian,[2] and is most common in the Carboniferous and Permian deposits. If any of the species included in the genus *Myophoria*, by Bronn, belong to this group, it must have been represented during the Triassic epoch.

Schizodus ovatus.

(PLATE II, Fig. 11, *a*, *b*.)

Axinus (*Schizodus*) *ovatus*, MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. Dec. 1858, 262.
Comp. *Schizodus truncatus*, King, Permian Fossils England, p. 193, pl. xv, fig. 25 to 29, inclusive.

Shell longitudinally ovate, moderately convex, the most gibbous portion of the valves being slightly in advance of the middle. Anterior side broader than the other, but somewhat narrowly rounded; posterior side more contracted—compressed and obliquely truncated above, and subangular below; base forming a regular semi-ovate curve, the most prominent part of which is in advance of the middle. Cardinal margin short, straight, and intersecting the obliquely truncated posterior edge at an angle of about 130°. Beaks rather elevated, incurved at right angles to the hinge, and placed a little in front of the middle; posterior umbonal slopes prominently rounded, or subangular from the beaks to the postero-basal extremity. (Surface, muscular, and pallial impressions unknown.)
Length, 0.65 inch; height, 0.45 inch; convexity, 0.32 inch.

This species is very closely related to *S. truncatus* of King, and may possibly prove to be identical, when a direct comparison of specimens can be made. It is more nearly like his fig. 27, pl. xv (Permian Fossils) than any of the other varieties represented by him, but differs in being more sharply rounded in front, while its beaks are a little more depressed. Its posterior umbonal slopes appear also to be less prominent than in any of his figures of *S. truncatus.*

Locality and position.—South Cotton-Wood Creek, Kansas; in Permian magnesian limestone. It also occurs there in lower beds containing many Coal Measure species. (Type 3960.)

FAMILY NUCULANIDÆ.

Shell longer than high, subovate, oblong or subelliptical, equivalve, usually somewhat pearly within; hinge provided with small interlocking cardinal plates or denticles, as in the *Nuculidæ;* ligament internal or external; margins of valves smooth within; pallial line more or less sinuous.

Animal with mantle margins open, fringed, and usually provided with ventral lobes; labial palpi very long, convoluted; siphons rather long, slender, partly united and retractile; gills plumose, attached throughout their length. Foot deeply grooved, geniculate, and usually with serrated margins.

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[1] *Anodontopsis securiformis,* of McCoy, is apparently an Upper Silurian example of this genus.

[2] Murchison, Verneuil, and Keyserling refer to this genus, a species (*S. devonicus*) from the Devonian Rocks of Russia.

This group has been divided by Conchologists into two subfamilies, as follows:—

1. Nuculaninæ.
Shell pearly within; ligament internal.
Including *Nuculana* and *Yoldia.*

2. Malletinæ.
Shell with ligament external; valves sometimes slightly pearly within.
Includes *Malletia* and *Neilo.*

SUBFAMILY NUCULANINÆ.

Genus YOLDIA, MÖLLER.

Yoldia, H. P. C. MÖLLER, Kröyer's Nat. Tid. 1842, IV, 91; Ind. Moll. Grœn. 18; Cf. Zeitschr. f. Mal. 1844, 12.
Synon.—*Maldia*, GRAY (misprint), 1847. *Leda* and *Nucula* (sp.), of various authors.
Etym.—Dedicated to the Countess Yoldi.
Examp.—*Nucula limatula*, SAY.

Shell ovate or subelliptical, subequilateral, more or less compressed; posterior side narrower than the other. Surface smooth, striate or obliquely sculptured, and covered with a polished epidermis. Margins smooth within; inner laminæ slightly pearly. Hinge plaits small, and more or less numerous on each side of the beaks; cartilage occupying a pit under the beaks. Pallial line distinctly sinuous.

The genus *Yoldia* is closely allied to *Nuculana*, but may be distinguished by its deeper pallial sinus, and usually less prominent beaks. From *Nucula*, which it resembles in the crenulated character of the hinge, it will be readily distinguished, not only by the presence of a sinus in the pallial line, but by its less distinctly nacreous, and differently formed shell. The animals in these two genera are also different.

We are not sure this genus dates back to the Palæozoic epoch, though some of the Carboniferous and Permian species present exactly the form and external appearance of true Yoldias. Some of the Triassic and Jurassic species usually referred to the closely allied genus *Nuculana* (= *Leda*), probably also belong to this genus. Several of the Cretaceous species, figured by D'Orbigny in the Palæontology of France, under the names *Nucula* and *Leda*, seem to be typical Yoldias.

The genus *Yoldia* was represented by a few species during the Tertiary epoch, and probably attains its greatest development in the existing seas. The recent species are chiefly found in northern and antarctic seas, and occur on the coast of Greenland, Kamtschatka, Massachusetts, &c.

Yoldia? subscitula.

(PLATE II, Fig. 4, *a*, *b*.)

Leda subscitula, MEEK & HAYDEN, Trans. Albany Inst. IV, March 2d, 1858.

Shell of medium size, rather narrow subovate, moderately convex in the central and umbonal regions. Posterior half more compressed and subrostrate, very narrowly rounded at the extremity; anterior extremity less narrowly rounded. Base forming a broad semi-ovate curve, the most convex part of which is slightly in advance of the middle; dorsal outline convex, and declining a little in front of the beaks, somewhat concave and nearly horizontal behind them. Beaks moderately prominent, and nearly central. Hinge straight or sloping slightly from the beaks, near which a few fine crenulations are visible in the cast.

Length, 0.50 inch; height, 0.26 inch; breadth or convexity, about 0.17 inch.

The only specimens of this species we have seen, are internal casts, which give no idea of the surface markings. We have also been unable to make out the nature of the muscular and pallial impressions, and have therefore only placed it in this genus from the close analogy of its form to typical species in more recent formations.

Locality and position.—Near the mouth of Smoky Hill fork of Kansas River, and on Cotton-Wood Creek, as well as at other localities in the Permian beds of northeastern Kansas. (Type 3957.)

FAMILY CRASSATELLIDÆ. (See page 34.)

Genus PLEUROPHORUS, KING, 1844. (See page 34.)

Pleurophorus ? subcuneatus.

(PLATE II, Fig. 3.)

Pleurophorus subcuneatus, MEEK & HAYDEN, Trans. Albany Inst. IV, March 2d, 1858.
Pleurophorus ? subcuneatus, MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. June, 1859, 29.

Shell small, longitudinally oblong, the basal and cardinal margins being parallel, and the extremities rather narrowly rounded; valves moderately convex; beaks depressed, and located near the anterior end. Hinge long, straight, or slightly arched; cardinal teeth unknown; posterior lateral teeth parallel to the hinge margin, and remote from the cardinal teeth. Impression of the anterior adductor muscle deep, subtrigonal, and located close to the margin—internal ridge on its posterior side well defined, ranging nearly vertically; impression of the pedal muscle distinct from, and located directly over, that of the anterior adductor; posterior muscular impression very faint. Surface with fine concentric striæ.

Length of a medium sized specimen, 0.54 inch; height, 0.24 inch; thickness or convexity, 0.16 inch.

In form and general appearance, as well as in the character and position of its anterior adductor muscular scars, and its posterior lateral teeth, internal ridge, &c., this species agrees quite well with the typical species of Prof. King's group *Pleurophorus.* It differs, however, in having the scar of its anterior pedal muscle nearly marginal, instead of farther back, while the casts show scarcely any traces of the radiating costæ generally well marked on those of that genus.

It also agrees very closely with a small shell figured by J. de C. Sowerby, under the name of *Unio phaseolus* (Trans. Geol. Soc. Lond. 2d ser. vol. V, p. 491), and subsequently referred, by Prof. Koninck, to the genus *Cardinia.* Indeed these shells are so closely similar, that, judging from the figures and descriptions we have seen of the European form, we have some doubts whether they may not prove to be specifically identical. We think it scarcely possible that they can belong to different genera. Possibly both should be referred to *Carbonocola*, McCoy (= *Anthracosia*, King).

This species will be known from our *P. occidentalis*, by its greater height in the anterior region, and more prominent antero-ventral border. It also seems to differ in being, as above stated, nearly or quite destitute of the radiating plications seen on that shell.

Locality and position.—Near the mouth of Smoky Hill fork of Kansas River; at the head of Cotton-Wood Creek, and at numerous other localities in north-eastern Kansas. From layers of yellow Magnesian Limestone of Permian age. (Type 4181.)

Pleurophorus? Calhouni.

(PLATE II, Fig. 13, *a*, *b*.)

Edmondia? Calhouni, MEEK & HAYDEN, Trans. Albany Inst. IV, March 2d, 1858.

Shell longitudinally subovate, gibbous over the oblique umbonal slopes. Extremities rather narrowly rounded; base forming a broad semi-elliptic curve, sometimes nearly straight along the middle; dorsal side declining rather gradually from the beaks posteriorly, and more abruptly in front. Hinge straight, apparently thickened within, so as to leave on internal casts a slightly impressed lanceolate area, along the cardinal region behind the beaks. Umbones moderately prominent, oblique, and placed a little nearer the anterior extremity than the middle. Anterior adductor muscular impression rather deep, broad ovate, and located near the buccal edge; scar of the pedal muscle small, oval, deep, and located near the margin of each valve, a little above the impression of the anterior adductor. Posterior muscular impression shallow; pallial line rather distinct (and undoubtedly simple).

Length (of an internal cast), 1.45 inch; height, 0.75 inch; convexity, 0.80 inch.

Since first referring this species with doubt to the genus *Edmondia*, we have satisfied ourselves that it cannot be retained in that genus; there being no traces left in well preserved internal casts, of the cardinal appendages for the attachment of the cartilage, as in *Edmondia*. Although we now place it provisionally in the genus *Pleurophorus*, we are not clearly satisfied in regard to its relations to that group; indeed, so far as we can determine from impressions of the hinge left in the matrix, it does not appear to have been exactly like that of the typical species of that genus.

This species may be at once distinguished from the last, by its larger size, proportionally shorter form, and less prominent internal ridge just behind the anterior adductor scar—as well as by its more prominent umbones, which are also placed farther back.

Locality and position same as last. (Type 4184.)

CEPHALOPODA.

Order **Tetrabranchiata.**

Family NAUTILIDÆ.

Shell curved, involute, or rarely spiral; outer or last chamber capacious, sometimes deflected from the curve of the inner whorls, and more or less straightened; aperture usually sinuous on the dorsal or outer side. Septa simple, or with a few undivided lateral lobes or flexures; concave on the side facing the aperture. Siphon varying in its position between the inner and outer, or dorsal and ventral margins, according to the genera and species; rarely (in older extinct groups) occupied by an internal organic deposit; nearly always piercing the septa backwards from the aperture; envelope usually solid and persistent.

For what is known in regard to the structure of the animal in the recent typical genus of this family, we are mainly indebted to Prof. Richard Owen, of London. According to this distinguished comparative anatomist, the powerful parrot-like mandibles of the recent *Nautilus pompilus* are surrounded by a fleshy lip, around which are four groups of labial tentacles, numbering twelve to thirteen each. Outside of these, on each side of the head, are thirty-six brachial tentacles or arms, arranged in a double series; the dorsal pair being expanded and connected so as to form a hood, which partly closes the aperture of the shell when the other appendages are retracted. The tentacles are laminated on their inner sides, and capable of being drawn within sheaths apparently homologous with the eight arms of the Cuttle-fish. There are also four ocular tentacles—one behind and one before each eye. The respiratory funnel is formed by the folding of a thick lobe which extends laterally on each side of the head, with the free edge directed backwards into the branchial cavity. The mantle is firm and muscular as far back as the line of the shell muscles, beyond which it is transparent. Its margin is entire, and extends to the edge of the shell. The siphon is vascular, and connected with the pericardium.

Most Palæontologists include in the family *Nautilidæ*, an extensive group of older fossil shells presenting a great diversity of forms and other characters: such, for instance, as *Phragmoceras*, *Gomphoceras*, *Endoceras*, *Orthoceras*, *Huronia*, *Aploceras*, &c.—probably belonging to one or more distinct families. As here defined, the family *Nautilidæ* is intended to include the following groups: *Nautilus*, *Discites*, *Trematodiscus*, *Temnocheilus*,[1] *Northoceras*, *Pteronautilus*,[2] *Lituites? Hortolus? Cryptoceras*, *Clymenia*, *Subclymenia*, *Aganides* (= *Aturia*), *Nautiloceras*, *Aploceras*, and *Trochoceras*, with probably some undescribed Jurassic, Triassic and older genera.

Genus NAUTILUS, Linnæus.

Synon.—*Nautilus*, Breynius, Dissert. Polyth. 1732, 12–14.—Linn. (part), Syst. Nat. ed. 10, 1758, t. i, 709.—Brug. Encyc. Meth. I, 1789, p. xvi.—Lamk. Prodr. 1799, 79; and Syst. 1801, 99.
Oceanus, Montf. Conch. Syst. 1808, p. 58–9.
Ammonites, Ib. 74–5, not (Breyn.—Linnæus).
Ellipsolithes (sp.), Sowerby, Min. Conch. I, 1814, 56 (not Montf. 1808).
Omphalia and *Nautilus*, De Hann, Mon. Amm. 1824.
Simplegas (sp.), Blainville, Dict. Sci. Nat. tom. 32, 185 (not *Simplegades*, Montf. 1808).
Etym.—ναυτιλος, a sailor or navigator.
Type.—*N. pompilius*, Linn., Linn.

Shell subglobose or more or less compressed; umbilicus closed or open; volutions coiled in the same plane, merely contiguous, or more or less deeply embracing. Septa simple or somewhat arched or waved on the lateral margins; siphon generally central or subcentral. Surface smooth or variously striate or costate and furrowed; in some of the older extinct species ornamented with nodes. Lip generally more or less sinuous on the dorsal and ventro-lateral margins.

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[1] In the June number of the Proceed. Acad. Nat. Sci. Phila. 1862, p. 147, the subgeneric name *Trematodiscus* was proposed by the writer and Mr. Worthen, for such fossil species as *Nautilus strigalis*, *N. Edwardsianus* and *N. omalianus*, Koninck; and *N. sulcatus*, *N. pinguis*, &c., Sowerby. Since that time we observe Prof. McCoy had proposed, in 1844 (Carb. Foss. Ireland), the name *Temnocheilus* for a group including some of the same forms. As his first species, however (*N. biangulatus*, Sowerby), and several of the others ranged by him under that name, differ considerably in form and surface characters from the types for which the name *Trematodiscus* was proposed, it may be convenient to restrict *Temnocheilus* to such forms as *N. biangulatus*, Sowerby; and *N. pinguis*, and *N. coronatus*, McCoy; and to retain *Trematodiscus* for those agreeing with its type as originally proposed. If it should be thought desirable, however, to group all these forms together, Prof. McCoy's name *Temnocheilus* would have to take precedence, as it was first published.

It is also worthy of note that Blainville had, in 1824 (Dict. Sci. Nat. tom. 32, p. 185) included some similar forms under the name *Simplegas*, adopted from Montfort. It will be remembered, however, that the type of Montfort's genus *Simplegades* (not *Simplegas*), is an *Ammonite* or *Ceratite*; while the first, or typical species of *Simplegas*, Blainville, is a true *Nautilus*.

In 1842, Mr. G. B. Sowerby adopted, in his Manual (p. 276), Blainville's name *Simplegas*, and figures as an illustration of the group *N. sulcatus*, Sowerby, a typical *Trematodiscus*. Although he writes the name *Simplegas*, he cites Montfort as the author of the group, and yet admits that the type of *Simplegades*, Montfort, has sinuous septa like *Ammonites*.

[2] The name *Pteronautilus* is proposed for a remarkable undescribed Permian genus, of which *Nautilus Seebachianus*, Genitz, is the type (see Dyas, p. 43, tab. 11). It may be characterized as follows:—

Genus **Pteronautilus**, Meek.

Shell with the involute body portion comparatively very small and globular in form, scarcely umbilicate. Outer chamber very large, and deflected from the involute body, its inner or ventral side being widely open, and the lateral margins greatly dilated, so as to form a very large wing-like expansion on each side.

Conchologists will readily understand that such a shell as this must have been inhabited by an animal differing widely in its structure from a living typical *Nautili*.

Of the large number of older fossil species referred to the genus *Nautilus*, some undoubtedly belong to distinct genera, while others fall into subgeneric groups, differing more or less from the recent typical forms. If we admit *Discites*, *Trematodiscus*, *Cryptoceras* and several other equally marked forms into this genus, we may regard it as dating back to the Silurian epoch. Species approximating the typical *Nautili*, however, did not exist, so far as known, before the Carboniferous period, and even the few of modern aspect then introduced, present peculiarities in their septa, or in the position of the siphon, that readily distinguish them from the more recent types; while the great majority of their supposed congeners of that epoch are still more aberrant. The same may also be said in regard to the known Permian species.

In the Triassic and Jurassic rocks, along with some of more modern aspect, we meet with a number of species which, from the lobed or sinuous character of their septa, and other peculiarities, seem to form sections or subgenera, and apparently in some instances, distinct genera. The Cretaceous and Tertiary rocks, as might be expected, contain a larger proportion of true *Nautili*, but even in the Tertiary, the older type of structure is repeated in the genus *Aturia*, of Bronn (= *Aganides*, Montfort?), which, with a ventral siphuncle, has deep lateral lobes in the septa, similar to those of *Goniatites.*

Some five or six recent species of *Nautilus* have been described by Conchologists. They are found in the Chinese and Indian Seas, Persian Gulf, &c. As they have rarely been seen alive, little is known in regard to their habits.

Nautilus eccentricus.

(PLATE II, Fig. 14, *a*, *b*.)

Nautilus eccentricus, MEEK & HAYDEN, Trans. Albany Inst. IV, 1858.

Shell small, somewhat compressed; volutions apparently not more than one and a half, not embracing, rounded excepting near the aperture, where the non-septate portion presents an oval transverse section. Umbilicus wide, shallow, and showing all of each whorl. Septa moderately concave; siphon small, placed about half way between the centre and the outer, or dorsal side. Aperture transversely oval. (Surface unknown.)

Length, 0.70 inch; height, 0.53 inch; breadth at the aperture, 0.43 inch; small diameter of aperture, 0.25 inch.

We have some doubts in regard to the propriety of retaining this species in the genus *Nautilus*, since it seems to consist of little more than one entire whorl, apparently surrounding an open central space. In this character (if it is not due to some accident), as well as in the eccentric position of the siphuncle, it would seem to present affinities to the genus *Gyroceras;* from which, however, it differs in having the whorls coiled so as to come in contact. Excepting in the rounded or non-sulcate character of the whorls, it appears to approach the group *Trematodiscus.*

Locality and position.—Near the mouth of Smoky Hill fork of Kansas River. Permian. (Type 4185.)

REPTILIAN AGE.

(JURASSIC PERIOD.)

RADIATA.

CLASS **ECHINODERMATA.**

ORDER **Crinoidea.**

FAMILY PENTACRINIDÆ.

Genus PENTACRINITES, MILLER.

Synon.—*Pentacrinites* (SCHLOT.), MILLER, Nat. Hist. Crinoid. 1821, 56.—GOLDF. Petref. Germ. I, 1826, 168.—ROEMER, Ool. 1836, 29; Kreid. 1841, 26.—BRON. Leth. Geog. 1836, 219.
Pentacrinus, AGASSIZ, Prodr. Mong. Ech. Mem. Soc. Sci. Nat. Neuchatel, 1835, 195; and various later authors.
Chladocrinus, AG. ib. 196.
Etym.—πεντὰς, five; κρίνον, a Lily.
Examp.—*Pentacrinites briareus*, MILLER.

Column more or less distinctly pentagonal, with central cavity small and rounded; provided with lateral branches or accessory arms arranged in verticils; segments ornamented with star-like sculpturing on their upper and lower surfaces. Body small, composed of five small or rudimentary basal plates, and fifteen larger radials, in five series of three each, without inter-radial pieces. Visceral cavity protected by a covering of numerous very small polygonal plates. Arms large, long, frequently bifurcating, and provided with numerous jointed tentacles.

Prof. Agassiz separates this group into two sections, as follows:—

1. **Pentacrinites** (proper).
   Column with lateral branches simple.
2. **Chladocrinus,** or **Cladocrinus.**
   Lateral branches of column themselves provided with verticillate branchlets.

Probably the most ancient known species of this genus are from the St. Cassian beds of the Tyrol, often referred to the Trias, but by some included in the Jurassic system. The genus attained its greatest development during the deposition of the Jurassic rocks; but occurs in the Cretaceous and Tertiary deposits, and is represented by a few species in our existing seas. It has not been found in this country east of the Black Hills.[1]

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[1] It is an error, we think, to quote *Pentagonites*, Rafinesque (Jour. de Phys. LXXXVIII, 1819, 429), described by him, with other fossils from some of the Palæozoic rocks of the Western States, as a synonym of *Pentacrinites*. On the contrary, his type was more probably one of the Silurian Crinoids

Pentacrinites asteriscus.

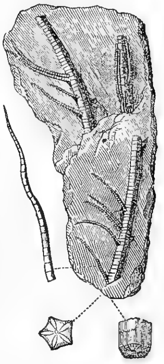
(PLATE III, Fig. 2, *a*, *b*, and annexed cut?)

Pentacrinus asteriscus, MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. March, 1858, p. 49; MEEK & HAYDEN, ib. Oct. 1860, 419.

Comp. *Pentacrinus scalaris*, GOLDF. Petrefact. Germ. tab. 52, fig. 3; also Quenstedt Der. Jura, tab. 13, figs. 49–57.

Our knowledge of this crinoid is entirely derived from detached segments of its column, and other parts, as seen imbedded in a sandy matrix, cemented by calcareous matter. The joints of the column may be characterized as rather small, thin, very symmetrical pentagonal star-shaped bodies, the rays of which are usually a little longer than wide, and somewhat acutely angular at their extremities. Through the centre of each of these joints, there is a minute circular perforation, from which five lance-oval petaloid areas radiate, one to the extremity of each of the angles; the areas being bounded on each side by rather narrow, slightly elevated crenulate margins.

This description applies more particularly to the largest sized specimens, measuring about 0.18 inch across from point to point of the opposite angles (see Pl. III, fig. 2, a, *b*.) Associated with these, there are smaller joints, varying from 0.05, to 0.10 inch in diameter, having proportionally shorter and broader rays, which are usually less angular at the points than those of the larger ones. These may possibly prove to belong to another form, though it is quite as probable they are only joints of smaller individuals of the same species. The annexed cut represents some of these smaller less distinctly angular columns, from a locality on North Platte River.



Pentacrinites asteriscus?
North Platte River.

The specimens are all so very similar to the corresponding parts of *P. scalaris*, Goldfuss, that after more careful comparisons we are inclined to the opinion that they may possibly prove to belong to that species. Still, as they are all much smaller than those figured by Goldfuss and Quenstedt, and none of them have the points of the rays so rounded, we have concluded to retain our name until their difference or identity can be established by a comparison of specimens.

Locality and position.—Associated with other Jurassic fossils at the southwest base of Black Hills; and opposite Red Buttes, North Platte River. (Type 220.)

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for which Prof. Hall subsequently proposed the name *Heterocrinus* (Pal. N. Y. Vol. I); which has a distinctly pentagonal column, and is common in the Blue Limestone of the age of the Hudson River Group, in Ohio, Kentucky, and Indiana, as well as New York. Rafinesque's name, however, cannot be adopted for this Palæozoic group, since he gave no characters by which either the genus or the typical species, could be certainly identified.

MOLLUSCA.

CLASS **BRACHIOPODA.**

FAMILY LINGULIDÆ. (See page 1.)

Genus LINGULA, BRUGUIÈRE.

Synon.—*Lingula*, BRUG. Encyc. Méth. I, 1792, tab. 250.—CUVIER, Tab. Elem. 1798, . . . ; Ann. Mus. I, 1802, 69.—LAMK. Prodr. 1799, 89; Syst. Ann. 1801, 140.

Pharetra, BOLTEN, Mus. Bolt. 1798, 2d ed. 1819, 111 (not Hübn. 1816).

Etym.—*Lingula*, a little tongue.

Type.—*Lingula anatina*, LAMK.

Shell oblong or more or less oval, depressed, thin, gaping at each end, and rounded or subtruncate in front, and more or less pointed at the beaks—consisting of alternate corneous and testaceous laminæ, the former of which are fibrous and the latter tubular; composition largely phosphatic. Valves both moderately convex, held together by the action of muscles; beak of ventral valve more pointed and prominent than that of the other. Surface smooth, or marked by concentric lines, sometimes crossed by radiating striæ. Peduncle long, thick, cylindrical, fleshy, and flexible.

On the inner side of the shell of the typical forms of this genus, the marks of the visceral sac and the scars of the complex muscular system occupy most of the posterior half of the valves. In the dorsal or shorter valve, this visceral area has a somewhat rhombic or suboval form, and in the ventral valve its outline is ovate-cordate, or more or less flabelliform. The area thus designated is usually thicker in both valves than other parts of the shell, especially in old examples, so as to leave a slight impression on internal casts.

Of the muscular impressions, the form and position of which have been noted, there are twelve in the dorsal, and thirteen in the ventral valve. The scar of the peduncular muscle is situated immediately within the beak of the ventral valve; and just in front of it is the scar left by the divaricator muscles (of Hancock = posterior adductors of Woodward). At the anterior extremity of the visceral area, in the middle of the same valve, are the four very unequal scars of the posterior occlusor, and external and central adjustor muscles (of Hancock), which are so arranged and impressed as to impart a more or less trilobate outline to the anterior margin of the slightly more convex visceral area. Behind these, and just within each lateral lobe of the visceral area, are situated, one on each side, the widely separated anterior occlusor scars; and still further back, we see on each side those of the posterior adjustors, of which there are two on one side, and one larger on the other.

In the dorsal valve, there is no peduncular attachment, but the scar of the divaricator muscles is located nearly as in the other valve. The two anterior occlusor impressions of this valve are placed in contact, centrally, side by side, at the farthest anterior extremity of the visceral area; and just behind these, and a little separated from each other, are the two impressions of the posterior occlusor muscles. About midway between the latter and the posterior extremity of the visceral area are situated, near each lateral margin, the small scars of the posterior, external, and central adjustor muscles, of which there are four on one side, and three on the other, one of the latter being considerably larger than the others.

This genus is closely allied to the recently separated *Lingulepis*, and until the muscular impressions of the type of that proposed genus have been more clearly determined, there is some room for doubt whether or not it is really distinct. The principal differences yet observed between these two types, consist in the ovate subtrigonal form, and more attenuate beak in *Lingulepis;* and the much more distinctly trilobate visceral scar of its ventral valve. The visceral scar of its dorsal valve is also more flabelliform than in the typical Lingulas.

The genus *Lingula* was introduced at a very early period; at any rate, we find species in no way distinguishable from it, at least by any external characters, in some of the oldest of the Silurian rocks. Its remains are likewise found ranging through all subsequent formations, and several species are known to inhabit our existing seas. It seems to have attained its maximum development during the Silurian Age. The living species are found on the coast of California, the Sandwich and Philippine Islands, and on the shores of South and North Carolina, and the West Indian Island of St. Thomas. They inhabit shallow water, being generally found at low tide, with their long peduncle deeply penetrating the sand or mud.

Lingula brevirostris.

(Plate III, Fig. 3, *a*, *b*.)

Lingula brevirostris, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. March, 1858, p. 50; Id. Ib. Meek & Hayden, Oct. 1860, p. 419.

Shell subovate, varying to spatulate-ovate, very thin; lateral margins nearly straight, or somewhat convex, generally converging a little towards the beaks; front subtruncate or abruptly rounded; cardinal extremity narrowly rounded. Beaks obtuse and apparently not extending beyond the cardinal margin. Valves equally convex along the middle, and compressed towards the front and sides. Surface polished, and marked by fine, rather obscure lines of growth; on the surfaces of the inner laminæ traces of extremely fine longitudinal striæ are sometimes visible by the aid of a magnifier.

Length, 0.57 to 0.58 inch; breadth, 0.33 to 0.35 inch; convexity of the two valves, 0.16 inch.

This shell bears some resemblance to the Oolitic species *L. Beanii*, Phillips, but is generally broader toward the front, and more obtusely rounded at the cardinal extremity.

Locality and position.—Southwest base of the Black Hills, Idaho Territory—lower part of the Jurassic rocks of that region. (Type 206.)

Family RHYNCHONELLIDÆ.

Shell oval, oblong, subtrigonal or globose, fibrous and impunctate; hinge line curved, and without a proper cardinal area; dental laminæ varying with the genera; supports of oral appendages short and curved, or rarely developed into spiral calcified coils, which are always arranged vertically; muscular impressions much as in *Terebratula.*

Animal, in the living representatives of the family, attached by a muscular peduncle passing through an aperture under the beak of the larger valve; oral arms fleshy, spiral, flexible, and attached to the small curved processes of the smaller valve, towards the middle of the concavity of which the apices of the coils are directed; mantle not adhering, fringed with a few short setæ.

The shells of the *Rhynchonellidæ* have sometimes much the appearance of some forms of the *Terebratulidæ*, but may be distinguished by the absence of a rounded perforation at the extremity of the beak, by their impunctate structure, and differently formed brachial supports. From the *Spiriferidæ*, some types of which they also resemble in form, they are distinguished by the general absence of calcified spiral appendages, or where they do exist, by the apices of the spires being directed vertically, instead of towards the lateral extremities, &c.

This family includes the genera *Rhynchonella*, *Eatonia*, *Camarophoria*, *Pentamerus*, *Atrypa*, *Stenocisma*,[1] *Cœlospira*, and probably *Porambonites* and *Camerella.* The type for which *Leiorhynchus* has been proposed, and possibly a few other imperfectly known Palæozoic genera, may also be found to belong to this family. Only the typical genus is known to have living representatives in our existing seas—the other groups being extinct, and, so far as known, confined to the Palæozoic rocks.

Genus RHYNCHONELLA, Fisher, 1809.

Synon.—*Anomia* (sp.), Linnæus, and several early authors.
Rhynchonella, Fischer de Waldheim, Mem. Soc. Imp. Mosc. II, 1809, . . .—Blainville, Dict. Sci. Nat. t. XLV, 1827, p. 426.—D'Orbigny (part), Compt. Rend. XXV, 1847, 268.—Davidson, Brit. Foss. Brach. Genl. Int. 1854, 93, and of various other authors.
Trigonella, Fischer de Waldheim, Mem. Soc. Imp. Mosc. II, 1809 (not Da Costa, 1778).
Terebratulites (sp.), Schlot. Petref. 1820, 250.
Hypothyris, Phillips, Palæozoic Fossils, 1841, 55.—King, Ann. Mag. Nat. Hist. XVIII, 1846.
Hemithiris (sp.), D'Orbigny, Compt. Rend. XXV, 1847, 268.
Hemithyris, Bronn, Jahrb. F. Min. 246.
Acanthothiris, D'Orbigny, An. Sci. Nat. XIII, 1850, 223.
Etym.—ῥύγχος, a beak.
Examp.—*Terebratula acuta*, Sowerby.

Shell oval or trigonal-subglobose; with or without a mesial fold and sinus; surface with radiating striæ, costæ or plications—rarely smooth or spinous. Beak of larger valve acute, entire, prominent, and more or less curved; foramen variable

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[1] See note on page 16.

in size and form, and placed under the beak, by the incurving of which it is often closed or hidden; partly or entirely surrounded (the inner side being sometimes formed by the umbo of the smaller valve) by a deltidium, which is composed of two pieces, and merely rudimentary, or more or less well developed—sometimes produced in the form of a short tube. Hinge composed of two teeth in the larger valve, and two corresponding sockets in the other; the teeth being supported by dental plates which extend to the bottom of the valve. Apophyses of the smaller valve consisting of two short, flattened, moderately curved, and separate laminæ, which curve upwards and are attached to the hinge plate. Impressions of the adductor muscle in the smaller valve, quadruple, well defined, and separated by a short longitudinal mesial ridge; scars of the pedicle muscles occupying the cardinal plates. Shell and pedicle muscles of the larger or perforate valve occupying a saucer-shaped cavity at the base of the dental plates; those of the pedicle muscles narrow, elongate, and placed close to the inner bases of the dental laminæ—the remaining and larger portion of the cavity being chiefly occupied by the cardinal muscles, which are separated by a small ridge; above these is the small oval adductor scar.

Animal of *R. psittacea*, according to Mr. Davidson, with visceral mass confined to a small space near the beaks, and separated from the general cavity of the shell by a strong membrane, in the middle of which the mouth is situated. Upper lip plain, and the lower cirrhated. Alimentary canal passing through the deeply notched hinge plates, and terminating behind the point of insertion of the adductor muscle in the centre of the valve. Pallial veins consisting of four principal branches in each lobe, opening into larger sinuses. Margins of mantle fringed with a few short setæ.

This genus is of very ancient date, having been represented through the various geological epochs from the Silurian down to the present time. The species were quite abundant during some of the Palæozoic periods, as well as during the deposition of some of the Jurassic and Cretaceous rocks, particularly in Europe. The genus seems to be sparingly represented in the Tertiary deposits, and at present but two or three living species are known. The recent species are never so strongly costated or plicated, nor so short and subtrigonal in form as many of the older extinct ones, which, together with some other differences, have led several authors to think them not strictly congeneric.

Rhynchonella ————.

(PLATE III, Fig. 4.)

Our specimens of this shell are too imperfect to enable us to determine satisfactorily whether or not it is identical with any known form. In a genus like this, including so many species, often very closely allied, not much reliance can be placed upon identifications from a few imperfect specimens. It would be easy to point out characters in which it resembles some Jurassic species, but it seems, so far as can be seen, to be also quite as nearly like others of various ages, even amongst the Palæozoic forms.

Those we have examined are small, subrhomboidal, moderately convex, and have on the dorsal or smaller valve (we have not seen the other) about fifteen simple, obtusely angular plications, four or five of which are raised near the front, so as to form a moderately prominent, rather flattened mesial fold. The surface is also marked by fine, very obscure lines of growth, which are deflected upwards in crossing the plications, near the front.

Locality and position.—Southwest base of Black Hills (Jurassic), Dakota Territory. (Type 319.)

CLASS **LAMELLIBRANCHIATA.**

FAMILY OSTREIDÆ.

Shell more or less irregular, inequivalve, slightly inequilateral, lying upon, and generally attached by, the left valve. Beaks straight or curved; hinge edentulous; ligament subinternal; muscular impression nearly central, or behind the centre; pallial line obscure, simple.

Animal with its mantle entirely open, and provided with double, fringed edges, which are without distinct ocelli; foot obsolete; gills crescent-shaped, and separated from the palpi; labial appendages triangular, connected around the mouth by a plain membrane.

This family probably only embraces the three closely allied groups—*Ostrea*, *Gryphæa*, and *Exogyra;* the latter two of which are entirely extinct, excepting a single species apparently of *Gryphæa*. The curious extinct genus *Eligmus*, of Deslongchamps, is also placed here by some authors, but we are not well enough acquainted with these peculiar shells to express an opinion in regard to their affinities.

Genus OSTREA, LINNÆUS.

Synon.—*Ostracites*, *Ostreites*, *Limnostracites*, *Ostreum*, &c. (sp.), LLHWYD, KLEIN, and other pre-Linnæan authors.
Ostrea, LINNÆUS, Syst. Nat. ed. 10th, 1758, 696.—O. F. MÜLLER, Prodr. Zool. Dan. xxxi.—BRUG. Encyc. Méth. I, xiii.—LAMK. Syst. 1801, 132, &c.
Peloris, POLI, Test. Utr. Sic. 1791, 33.
Peloriderma, POLI, ib. II, 255.
Lopha, BOLTEN, Mus. Col. 1798 (2d ed. 117).
Alectryonia, FISCHER DE WALDHEIM, Mus. Dem. 1807, and Bull. Mosc. VIII, 1835.—CHENU, Man. Conch. II, 1862, 167.
Dendrostrea, SWAINSON, Malacol. 1840, p. 389.—G. B. SOWERBY, Conch. Man. 2d ed. 137.
Etym.—ὄστρεον, an Oyster.
Type.—*Ostrea edulis*, LINN.

Shell irregular, subnacreous, laminated, attached by the left or under valve; surface often ornamented by radiating plications, and more or less imbricating, or distinct marks of growth. Upper valve flat or concave; lower valve convex, and having a prominent beak. Ligament occupying a pit or groove in the cardinal area of each valve. Muscular impression subcentral.

Several authors include as subgenera under this group, *Gryphæa*, Lamarck, and *Exogyra*, Say; and it cannot be denied that we are sometimes at a loss to determine to which of these genera a given species should be referred. Indeed, in some cases, we find different individuals of the same species presenting various gradations between the true Oysters and Gryphæas. Whether founded in nature or not, however, these groups are convenient, and can generally be distinguished without difficulty.

The genus *Ostrea* appears to date back as far as the Carboniferous epoch; at any rate, Prof. Koninck has described one species (*O. nobilissima*) from rocks of that age in Belgium. Murchison, Verneuil & Keyserling have also referred to this genus another species (*O. matercula*) from the Permian rocks of Russia. As these, however, are, so far as our knowledge extends, the only evidences we have of the existence of this genus previous to the beginning of the Triassic period, it would seem to have been very sparingly represented, even during the deposition of the latest of the Palæozoic rocks.

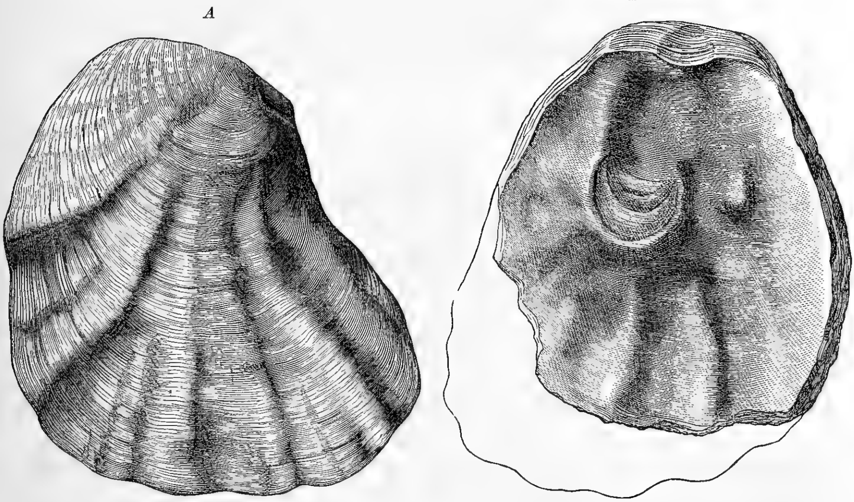
Oysters are not uncommon in the Triassic deposits, and the number of species increases as we ascend through the later formations. The genus is also well represented, as every one knows, and probably attains its greatest development in the bays, estuaries, &c. of the present epoch.

Ostrea Engelmanni.

Ostrea Engelmanni, Meek, Proceed. Acad. Nat. Sci. Phila. July, 1860, 311.

This species is only known from imperfect detached valves, all of which are much compressed, thin, and present a more or less irregular subovate outline. The beak is truncated, and provided with a broad but short area. The surface is ornamented by from seven to about fifteen irregular, moderately distinct, rather rounded, radiating plications, not usually extending more than about half way from the free margins towards the umbo. Lines of growth regular, rather faint, and not imbricating. Internal margins not crenate near the hinge. Muscular scar rather large, oval, and well defined.

Length of largest specimen, 3.50 inches; breadth, 3 inches.



Ostrea Engelmanni.

A. Outside under? valve.

B. Inside of another specimen.

This species bears some general resemblance to *O. Marshii*, of Sowerby, but is a thinner and more compressed shell, with less prominent, and much less angular plications or costæ. Its area is also proportionally much shorter.

Locality and position.—Jurassic beds at Red Buttes, on the north branch of Platte River, Dakota Territory, lat. 42° 50′, long. 106° 40′ west. Collected by the Expedition under the command of Capt. J. H. Simpson, of U. S. Top. Engineers. (No. 1884.)

Genus GRYPHÆA, Lamarck.

Synon.—*Auricularia*, *Auriculites*, &c. (sp.), of Llhwyd and other early writers.
Gryphæa, Lamarck, Syst. An. 1801, 398.—Roissy, Mol. 1835, 202.—Blainv. Dic. Sci. Nat. t. 19, 1821, p. 533.—Risso, Hist. IV, 1826, 290.
Griphæa, Blainv. Malacol. 1825, 522.
Pycnodonta, Fischer de Waldheim, Bull. Mosc. VIII, 1835.
Etym.—γρύψ, a Griffin.
Examp.—*Gryphæa arcuata*, Lamk.

Shell generally free, especially in the adult state. Lower valve deep; beak prominent and distinctly incurved, and but slightly oblique. Upper valve flat or concave; beak usually truncated. Hinge, ligament, and muscular and pallial impressions as in *Ostrea*. (Animal unknown.)

The shells of this genus differ from those of the true Oysters in being more regular, in having the lower valve deeper, and particularly with its beak more prominent and incurved. They seem also to be scarcely ever plicated as we often see in the genus *Ostrea*. From *Exogyra* they differ mainly in having the beak of the lower valve curved upwards and inwards, instead of to one side, as well as being probably always without the large plications sometimes observed in *Exogyra*. Most of these distinctions, however, particularly the prominence and incurving of the beak, sometimes become so faintly marked that it is not always easy to separate the species of these three groups.

This type appears to have been first introduced during the deposition of upper members of the Triassic series; at any rate, a few species have been referred to it from the St. Cassian beds of the Tyrol usually referred to that epoch. It is more frequently met with in the Liassic and other members of the Jurassic system, and probably attained its maximum development during the deposition of the Cretaceous rocks. A few species have been referred to this genus from the Tertiary rocks of Europe; though it is doubtful whether or not they are true Gryphæas. No living examples of the group are known.

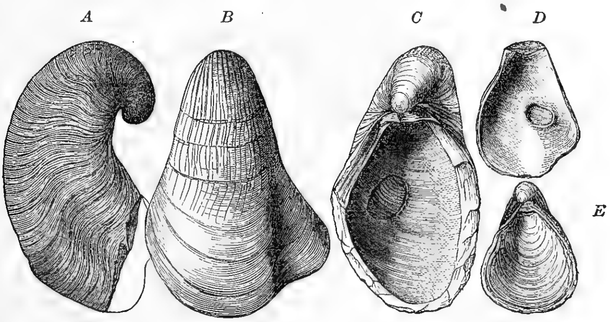
Gryphæa calceola, var. **nebrascensis.**

(Plate III, Fig. 1*a*, *b*, *c*, *d*, *e*, and annexed cuts.)

Gryphæa calceola, Quenstedt, Handb. Petref. tab. 40, fig. 29–31.—Quenstedt, Der Jura, 1856, 352, tab. 48, figs. 2, 3, 4, and 5.—Meek, MSS. Capt. Simpson's Rept. Utah.
Gryphæa calceola, var. *nebrascensis*, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1861, 437.

Shell, when normally developed, subovate in small specimens, but becoming more elongate and proportionally narrower with age. Under valve very thick in the umbonal region; beak prominent, narrow, produced, and strongly incurved; anterior side with a more or less defined sulcus, which never extends quite to the point of the beak; area triangular, arcuate, extending close up under the curve of the beak, and provided with a distinct cartilage depression; muscular scar small, shallow, oval, and located near the anterior side; surface ornamented on the gibbous back of the umbo by distinct, irregular, radiating striæ, usually extending to near the middle on mature specimens, while the space between this and the ventral margin has only moderately distinct concentric striæ and marks of growth. Upper valve ovate, nearly flat on the outside, or a little convex near the beaks, and more or less concave near the middle, usually concave on the inner side towards the cardinal extremity, which is thick and truncated; surface with rather distinct concentric marks of growth.

Length, from the most prominent part of the umbo to the ventral extremity, 2.70 inches; breadth near the ventral extremity, about 1.20 inch; convexity, 0.73 inch. (Type No. 1881.)



Gryphæa calceola, var. *nebrascensis*.

A. Side view lower valve. *B.* Under side same. *C.* Inside same. *D.* Inside view of an upper valve. *E.* Upper view of a small specimen with the two valves united.

The normal form of this shell, as may be seen by the above cuts, agrees so very nearly with Quenstedt's *G. calceola*, that we cannot but regard it as most probably only a variety of that species. It has the same narrow, elongated, arcuate form, radiately striated umbo, and general appearance of the fully developed specimen of *G. calceola*, represented by Quenstedt's fig. 1, pl. 48, above cited, excepting that the beak of the under valve seems never to be quite so arched over and produced; while the sulcus along its anterior side of the exterior is not continued so nearly to the point of the beak.

Along with the form above described, we have from the same and other localities a few specimens with the point of the beak slightly truncated by a small scar of attachment, much as we see in fig. 4, pl. 48, of Quenstedt, referred by him provisionally to *Ostrea calceola*, Goldf.

At some localities nearly all the specimens have the beak truncated, and many of them seem to have been attached by so large a surface as to have entirely obliterated the umbo of the under valve, thus giving them all the characters of a true Oyster. Fig. 1*a*, *b* and *d*, Pl. III, represent some of these specimens, one of which, fig. 1*d*, will be seen to present very nearly the form and general appearance of fig. 2, pl. 48, Quenstedt, the most extremely abnormal type of the series. Between these extremes we find every intermediate gradation, so that it seems to be impossible to base specific distinctions upon these differences. We are, therefore, inclined to regard these shells as all belonging to one variable species, the differences being probably caused by the more or less favorable conditions of different localities or particular positions. Where the conditions were favorable, the shells attained a larger size, grew more symmetrically, and present the normal form of a true *Gryphæa;* but where exposed to the action of waves or too strong currents, they were probably more firmly attached, are smaller, more irregular in form, and have the umbo sometimes partly, sometimes entirely obliterated by the large scar of adhesion, which in a few extreme cases occupies the whole lower surface of the under valve.

From Quenstedt's figures and description of *Gryphæa calceola*, it is evident he found it presenting precisely similar variations, or at any rate, that he found a similar gradation of forms that he refers to the one species, *Gryphæa calceola.* Whether or not our shells really belong to the same species as those figured by Quenstedt, or to a closely allied representative form, it is not easy to determine, without an extensive series of specimens for comparison from the American and European localities. In the absence of such a series we have referred our shells provisionally to Quenstedt's species.

Locality and position.—The forms represented by the foregoing cuts, *A, B, C, D, E*, are from the Jurassic beds of Wind River Mountains, in the southern part of Dakota Territory. Some smaller, but similar specimens with other less regular forms, were found in Red Buttes, further east in the same Territory; also at Big Horn Mountains. The specimens figured on Pl. III, are from the same position at the southwestern base of the Black Hills, Dacota Territory.

FAMILY PECTINIDÆ. (See page 48.)

SUBFAMILY PECTININÆ. (See page 48.)

Genus CAMPTONECTES, AGASSIZ.

Synon.—*Pecten* (sp.), SOWERBY, Min. Conch. III, 1818, 3.—ROEMER, Die Vert. des Nord. Kreid. p. 50.—D'ORBIGNY, Pal. Franc. III, p. 592, and of various others (not MÜLLER).

Camptonectes, AGASSIZ, MSS.—MEEK, Smithsonian Catalogue Jurassic Fossils of North America.

Etym.—καμπτος, curved; νηκτης, a swimmer.

Examp—*Pecten lens*, SOWERBY.

Shell thin, subequivalve, lenticular, closed; hinge generally short, straight, edentulous; ears compressed, anterior one of the right valve separated from the margin below by a well defined, often deep, byssal sinus. Surface ornamented with radiating, impressed striæ, which curve strongly outwards in approaching the lateral margins, and often present a punctate appearance produced by the crossing of regular concentric striæ. Muscular impressions faint, apparently as in *Pecten.* (Animal unknown.)

Prof. Agassiz proposes this genus for the reception of such species as *Pecten lens*, and *P. obscurus*, Sowerby; *P. striato-punctatus*, Roemer, *P. virgatus*, Neilson, &c. It will probably be also found to include several nearly smooth or concentrically striated Jurassic and Cretaceous forms, since we find faint traces of curved, radiating or divaricating striæ on *P. cottaldinus*, of Sowerby, which to the unassisted eye seems to be only marked with concentric lines. It is likewise even possible, we think, that this genus may be found to include some Cretaceous species with straight, rigid, radiating costæ, such as *P. galliennei* and *P. rotomagensis*, D'Orbigny, for on both of these shells, which are ornamented with straight, radiating costæ, we observe an entirely distinct system of curved, radiating, or divaricating striæ, which on the lateral margins cross the costæ obliquely; while these shells have the form and deep byssal sinus of the typical *Camptonectes*. Still, they may present some differences in the nature of the hinge or interior that, along with their surface markings, would place them in a distinct genus.

The typical species of this genus will be at once known from all the other groups of *Pectinidæ*, by their peculiar ornamentation alone. That these and various other fossil and recent types usually referred to the genus *Pecten*, should be placed in different genera from that group, as typified by the recent *P. Jacobius*, *P. maximus*, &c., as maintained by Prof. Agassiz, cannot be reasonably doubted.

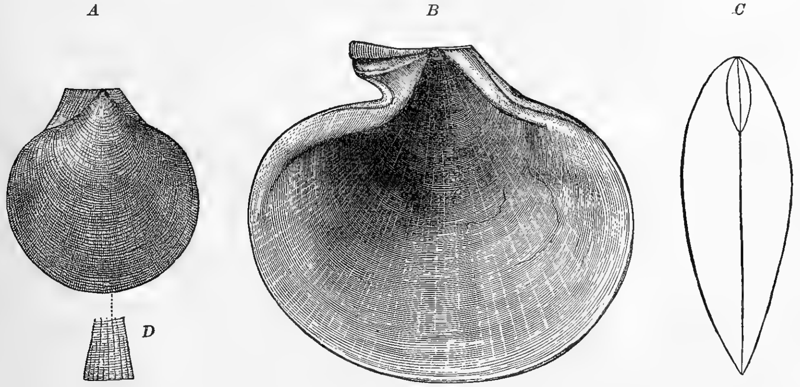
This genus was introduced during the Jurassic epoch, and ranges through several members of the Cretaceous system, the deposition of which it seems not to have survived.

Camptonectes bellistriatus.

Pecten bellistriatus, Meek, Proceed. Acad. Nat. Sci. Phila. July, 1860, 311.
Camptonectes bellistriatus, Meek, Smithsonian Cat. N. Am. Jurassic Fossils, 1864.

Shell very thin, compressed-lenticular, suborbicular; valves nearly equally convex; hinge line equalling two-fifths to one-half the transverse diameter of the valves; posterior ear very short or nearly obsolete, flat, and obliquely truncated; anterior ear larger, flattened, and marked by rather distinct lines of growth—in the right valve separated from the adjacent margin by a more or less angular sinus one-third to one-half as deep as the length of the ear, measuring from the beak. Surface striæ very fine, regular, sharply impressed, and increasing in number by the intercalation of others between as they diverge in extending from the umbonal region—so strongly arched as to run out on the hinge line near the beaks; concentric striæ fine, regular, closely arranged, and often nearly or quite obsolete on the flattened spaces between the impressed radiating striæ, to which latter they impart a sub-punctate appearance.

Length of a large shell, 2.65 inches; breadth from hinge to ventral margin, 2.26 inches; convexity, 0.64 inch.



Camptonectes bellistriatus.

A. Outside view of a small left valve. *D.* Enlargement of surface striæ of same. *B.* Inside view of a large right valve [the appearance of radiating markings within is an error in the engraving]. *C.* Outline of right and left valves united.

This species seems to be nearly related to *Pecten lens*, of Sowerby; but as no good figures or descriptions of the right valve of that species, from the original locality, have yet been published, and several distinct species have probably been confounded under that name, we are somewhat at a loss how to point out the distinctive characters of our shell. Sowerby's figures and description, especially, give us no very satisfactory characters for identification or comparison, and that given by Morris & Lycett (Monogr. Grt. Oolite, tab. ii, fig. 1) is also apparently of a left valve only, though from a better specimen than those figured by Sowerby. Compared with this, our shell is proportionally broader, and has a shorter hinge line, as well as shorter ears. From the species figured by Goldfuss, under Sowerby's name (Petref. Germ. ii, tab. xci, fig. 3), it will be readily distinguished, by its smaller posterior ear, and much deeper byssal sinus; this latter character will also distinguish it from the forms figured as *Pecten lens*, by Bronn (Leth. tab. xix, fig. 7).

The species figured by D'Orbigny (Geol. Russ. II, tab. xlii, 1) as *P. lens*, resembles that before us very nearly in form, the depth of its byssal sinus, and most of its other characters, but our species may be at once distinguished by its shorter obliquely truncated posterior ear. As near as can be determined from D'Orbigny's figures, the form described by him seems to be more coarsely striated.

Locality and position.—Red Buttes, and below there on the north branch of Platte River, Dakota Territory. Jurassic. (Type No. 680, Smithsonian Museum.)

Camptonectes? extenuatus.

(Plate iii, Fig. 6.)

Pecten extenuatus, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, p. 184.

Shell small, broad-ovate, or subcircular, compressed, lenticular; ventral margin regularly rounded; hinge line short (ears unknown). Surface of casts apparently only marked with concentric striæ.

Antero-posterior diameter, 0.90 inch; breadth from hinge to ventral margin, 0.98 inch; convexity, about 0.28 inch.

This species is rather abundant, but all the specimens we have seen are casts, which do not show the form of the ears very clearly. In one specimen, however, in removing some of the matrix from the hinge, we thought we saw traces of a deep sinus under the anterior ear of the right valve. If so, the form and general appearance of the shell would be that of *Camptonectes*, unless there may be differences in the surface markings. As stated above, the casts we have seen only show faint traces of concentric striæ; but as they are in sandstone, it is possible there may have also been fine curved radiating striæ, if not as in the typical species, at least faintly indicated as in *Pecten cottaldinus*, D'Orbigny.

The uniformly smaller size of this shell will alone distinguish it from the last, even if it should be found to agree in its surface sculpturing.

Locality and position.—North Platte below Red Buttes, Dakota; and southwest base of Black Hills, Dakota Territory. Jurassic. (No. 680, Museum Smithsonian Institution.)

Family PTERIIDÆ. (See page 27.)

Subfamily PTERIINÆ. (See page 28.)

Genus PTERIA, Scopoli.

Synon.—*Pteria*, Scopoli, Introd. Hist. Nat. 1777.—Gray, Zool. Proceed. 1847, 199.—Meek, Am. Jour. Sci. and Arts [2], XXXVII, 1864, 217.
Avicula (Klein), Brug (part), Encyc. Méth. 1792, pl. 177.—Cuvier (part), Tab. Elem. 1798; Anat. Comp. 1800; Règne An. 1817.—Lamk. Prodr. 1799; Syst. An. 1801, 134; Phil. Zool. 1809, 318, &c.
Margaritifera (sp.), Humph. Mus. Col. 1797, 44.
Pinctada, Link, Beschr. Rost. 1807 (not Bolten, 1798).
Unionium, Link, ib.
Anonica, Oken, Handb. d. Zool. 1815; Natgsch. f. Schulen. 1815, 652.
Perlamater (sp.), Schum. Ess. 1817, 107.
Etym.—πτερόν, a wing.
Examp.—*Mytilus hirundo*, Linn.

Shell obliquely subovate, or subtrigonal, fragile; surface smooth, striated, costated or subspinous—often with imbricating marks of growth; inequality of valves generally distinctly marked; byssal sinus in the anterior margin of the right valve well defined. Cardinal margin long, straight, and produced into more or less distinct wings at the extremities—the posterior wing being larger than the other. Hinge with usually one or two small cardinal teeth under the beak of each valve. The (simple) pallial line represented by a row of minute irregular scars, extending from the subcentral impression of the adductor muscle obliquely forward to the small anterior muscular scar beneath the beaks.

Amongst the numerous fossil species referred by various authors to this genus, there are, in addition to the several types we believe to belong to clearly distinct genera, others which differ sufficiently from the living typical species to constitute at least well marked sections. It is not our purpose, nor have we the necessary material at hand, to attempt to define here all of these various subordinate groups, though it becomes necessary to notice one of those including a species with which we have to deal. The section to which we allude may be designated as follows:—

Oxytoma, Meek.

Shell differing from the typical forms of *Pteria* (= *Avicula*), in being less oblique, proportionally shorter, more distinctly inequivalve, and usually more strongly costate—particularly on the left valve, around the pallial margins of which the costæ are sometimes produced in the form of free spines. The byssal sinus of the right valve is also much deeper and more sharply defined than in the typical species of *Pteria*.

Type *Avicula Munsteri*, Goldf. Petref. Germ. II, pl. cxxviii, 2 *a*, to *h*.[1] Also includes *A. costata*, Morris & Lycett, *A. digitata*, and apparently *Monotis interlævigata*, Quenstedt, and *A. cygnipes*, Phillips.

This section forms a transition from the typical *Avicula* to the genus *Eumicrotis*, and seems to be mainly, if not entirely, confined to the Jurassic rocks.

The genus *Pteria*, or *Avicula*, is so nearly related to the older extinct genus *Pterinia*, that the two groups are generally confounded, where the hinge and in-

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[1] Several species appear to have been confounded under the name *A. Munsteri*, by other authors. We regard the particular form figured by Goldfuss as the type of the section *Oxytoma*.

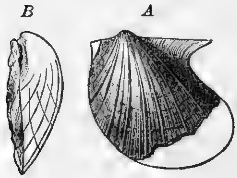
terior cannot be seen. They can be readily distinguished, however, when we have an opportunity to examine the hinge, which in *Pterinia* differs from that of *Pteria*, in the possession of a more or less broad cardinal facet, marked with linear cartilage furrows, but without a cartilage pit; as well as in having oblique posterior and anterior teeth not found in the true Pterias. From *Meleagrina* and *Mallœus*, which some authors include in this genus, the Pterias can be readily distinguished by obvious differences of form.

It will be very difficult to determine at what particular period this genus, as properly restricted, was first introduced, until the nature of the hinge of many extinct species can be determined. Palæontologists, who are often too much inclined to lose sight entirely of the existing types upon which so many genera of Mollusks were originally founded, refer to it many species from the Palæozoic rocks; but many of these older species are known to be true Pterinias; and it is more than probable, as already stated in the remarks on this family, that the Silurian, Devonian, and many, if not all, of the Carboniferous and *Permian* species referred to *Avicula*, will be found to belong to *Pterinia*, *Bakevellia*, &c., or to undescribed genera. Our present impression is, that typical species of *Pteria* did not exist previous to the Cretaceous epoch, and that probably none of the forms from rocks older than the Jurassic, or possibly from the Trias, can be properly included, even as distinct subgenera. The genus is represented in the Cretaceous and Tertiary deposits, but seems not to have been more extensively developed at any past time than at present in our existing seas. The living species are found on the coast of South America, of the British Islands, and in the Mediterranean and Red Seas, the Indian Ocean, &c.

Subgenus OXYTOMA.

Pteria Munsteri.

Avicula Munsteri, Bronn, Leoh. Zeitsch. 1829, 76.
Avicula Munsteri, Goldf. Petref. Germ. II, 131, cxviii, *a, b, c, d, e, f, g, h.*
Monotis Munsteri, Quenstedt, Wurtt. 341; Ib. Der Jura, II, 1856, 440, lx, 6.



Pteria Munsteri.
A. Outside view of left valve.
B. Profile of same.

Shell obliquely oval; hinge line less than the greatest parallel diameter of the valves, and ranging at an angle of 55° to 60° above the oblique longer axis of the shell; anterior margin sloping with a graceful backward curve into the rather narrowly rounded postero-basal extremity; posterior margin ascending forward nearly parallel with the anterior outline to the wing, where it curves rather abruptly backward so as to form a distinct rounded sinus. Left valve rather gibbous; beak convex, and projecting slightly beyond the hinge margin; posterior ear flattened, subtrigonal, and terminating behind in a mucronate angle, but not extending so far back as the postero-basal margin; anterior ear small, rather convex—form unknown. Surface (left valve) ornamented by about ten to fifteen moderately distinct slender radiating costæ, separated by spaces four to six times their own breadth. At the middle of each of these spaces there is usually a smaller rib, which dies out before reaching the umbo; and between each of these and the principal ribs, still smaller radiating striæ are seen—the whole being crossed by a few small marks of growth, and (probably on well preserved specimens) concentric striæ.

Diameter at right angles to the hinge, about 0.93 inch; do. parallel to the same, about 1 inch; convexity of left valve, near 0.24 inch.

We have referred this shell (provisionally) to *Avicula Munsteri*, of Bronn, rather because the imperfect specimens we have yet seen do not exhibit any reliable characters by which it can be distinguished, than from being satisfied that it is really identical. The few specimens in the collection consist of imperfect left valves, none of which give any idea of the form of the anterior wing; while their finer surface markings are nearly obliterated by exfoliation and weathering. It is more than probable that perfect specimens showing the nature of the surface markings of both valves will be found to present characters by which this shell may be distinguished from *Avicula Munsteri;* if so, it may take the name *Pteria mucronata*, or *Avicula mucronata*, if the latter generic name is retained.

Locality and position.—Wind River Valley, Dakota Territory. Jurassic. (Type 1893.)

Genus EUMICROTIS, Meek. (Page 53.)

Eumicrotis curta.

(Plate iii, Fig. 10, *a*, *b*, *c*, *d*.)

Avicula curta, Hall, 1852, Capt. Stansbury's Rept. Grt. Salt Lake Exp. 412, pl. 2, fig. 1, *a*, *b*.
Avicula (Monotis) tenuicostata, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. March, 1858, 50.
Monotis curta, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Oct. 1860, 418.
Eumicrotis curta, Meek, Smithsonian Check List N. Am. Jurassic Invert. Fossils, 1864.

Shell suborbicular, very slightly oblique, usually a little higher than long, moderately convex, and nearly equivalve; anterior side more or less rounded; ventral and postero-ventral margins rounded. Posterior border ascending obliquely forward, and sometimes slightly concave in outline above. Hinge margin straight, and considerably shorter than the length of the shell, compressed behind, so as to form a very short, more or less angular wing, which is sometimes nearly obsolete; rounding or very obtusely angular in front of the beaks, but not terminating in a wing. Beak of left valve small, and rising a little above the hinge; that of the other valve more compressed, and scarcely distinct from the cardinal margin—both located slightly in advance of the middle. Byssal sinus small, rather deep, angular, and connected with a narrow external groove extending nearly parallel with the hinge margin to the beak. Surface of left valve ornamented by radiating lines; that of the right valve generally only marked with concentric striæ.

Length, 0.60 inch; height, 0.64 inch; breadth or convexity, 0.26 inch.

The radiating lines of the left valve are regular, and usually rather smaller than the depression between; they seem to be always simple, though many of them die out before reaching the beaks. On the right, or smaller valve, they are always very obscure, and often obsolete, while the concentric striæ, in most cases, are moderately distinct. In adult shells, the hinge line is often proportionally shorter than in smaller individuals.

This species varies in form, some of the specimens being longer, and some shorter than wide. Those figured by Prof. Hall are in a bad state of preservation, and give an imperfect idea of the characters of the species; though we are satisfied, from direct comparison with other specimens obtained at the same locality, as well as with those collected by Capt. Stansbury, that our shell belongs to this species.

In form, surface markings, and indeed in almost all its characters, this shell agrees so very closely with *Monotis substriata*, Munster, that we are strongly inclined to the opinion that it will, on comparison, prove to be identical. It is generally a little less oblique than the figures of that shell given by Goldfuss, Quenstedt, and others, but varies in this respect. Were it not that some authors describe *M. substriata* as being plano-convex, while the two valves of our shell are nearly equally convex; and that none of the descriptions we have read mention any difference in the distinctness of the radiating striæ on the two valves, we would scarcely hesitate to refer the specimens now before us to *M. substriata*.

Locality and position.—Southwest base Black Hills. Jurassic. (Type No. 205.)

FAMILY TRIGONIIDÆ. (See page 57.)

Genus TRIGONIA, BRUGUIÈRE.

Synon.—Trigonia, BRUG. Encyc. Méth. I, 1789, xiv, pl. 237.—LAMK. Prodr. 1799, 86; ID. Syst. An. 1801, 116, and An. du Mus. IV, 1804, p. 351.—ROISSY, Mol. VI, 1805, 392, &c.

Lyrodon, G. B. SOWERBY, Genera Shells, 1833, fasc. 41.

Lirodon, BRONN, Leth. 1837 (sec. ed.) 367 and 700.

Lyriodon (part), GOLDF. Petref. Germ. II, 1837, 196.—BRONN, Jahrb. 1838, p. 108.

Etym.—τρίγωνος, three cornered.

Type.—Trigonia scabra, LAMK.

Shell subtrigonal, longitudinally ovate, elongate, or subcircular; postero-dorsal region often provided with a more or less distinctly defined escutcheon or corselet. Surface ornamented with radiating, oblique, or concentric costæ or rows of nodes; rarely smooth. Beaks usually elevated. Ligament short and prominent. Hinge thick, composed of two large diverging, elongate, transversely furrowed teeth, in the right valve, and three or four in the left, furrowed only on one side. Impressions of adductor muscles usually well defined, the anterior being located near the beaks. Scar of posterior pedal muscle located a little above, and in front of, the impression of the posterior adductor; antero-pedal scar generally placed within the cavity of the beaks, sometimes wanting in the right valve.

Many of the extinct species generally referred to this genus differ so widely in form and surface ornamentation from each other, as well as from the living Trigonias, as to leave room for doubts whether or not they really all belong to one and the same genus. These differences attracted the attention of Prof. Agassiz, who separated the several types into distinct sections, which he accurately describes in his excellent monograph of the genus. These sections may be briefly characterized as follows:—

1. "Les Scaphoides," AGASSIZ.

Shell subtrigonal, longer than high; anterior side short and truncated; posterior side long and very abruptly rounded or subangular at the extremity. Dorsal corselet large and nearly smooth, excepting the lines of growth; not defined by a ridge or sulcus on either side. Surface ornamented with varices in front, and more or less nodose, transverse or oblique costæ on the flanks.

Type.—Trigonia navis, LAMK. (*Jurassic and Cretaceous.*)

2. "Les Clavellees," AGASSIZ.

Shell more rounded in front than in the last group; corselet well developed and often bounded by a ridge on either side, sometimes with strong marks of growth. Surface ornamented with more or less nodose costæ, which pass from the margins of the corselet obliquely downwards and forwards, often becoming broken up into a series of isolated tubercles on the sides and front of the valves.

Example.—T. clavellata, SOWERBY. (*Mainly Jurassic.*)

3. "Les Carrees," AGASSIZ.

Shell shorter and more truncated at each extremity than the last; also with less regular costæ on the flanks, and a larger and more compressed corselet. Marks of growth often distinct on the corselet.

Example.—T. quadrata, AG. (*Upper Jurassic and Cretaceous.*)

4. "Les Scabres," AGASSIZ.

Shell rounded and gibbous in front, elongate, narrowed and subrostrate behind. Corselet separated from the flanks by a more or less distinct groove; ornamented with transverse costæ. Flanks and front with tuberculose, or subspinous costæ, which pass from the margins of the corselet to the base and front, those on the anterior part of the valves curving forward.

Example.—T. aliformis, SOWERBY. (*Mainly Cretaceous.*)

5. **"Les Ondulees,"** Agassiz.

Shell intermediate in its ornamentation between the last and the next following groups; corselet much as in "*Scaphoides;*" sides and front with longitudinal, generally smooth costæ, abruptly curved upwards behind.

Example.—T. undulata, Fromh. (*Jurassic and Cretaceous.*)

6. **"Les Costees,"** Agassiz.

Shell ornamented on the flanks and front with prominent, generally smooth longitudinal costæ, with scarcely visible marks of growth between. Corselet very distinct, and separated from the flanks by a well defined ridge, formed usually of flattened imbricating prominences; ornamented with numerous small tubercles, or tuberculate costæ, and two radiating crenulated ridges.

Type.—T. costata, Lamk. (*Jurassic and Cretaceous.*)

7. **"Les Lisseees,"** Agassiz.

Shell depressed, elongate, and rounded at both extremities, smooth, or rarely with obscure traces of concentric costæ in front; lines of growth not strongly marked.

Example.—T. longa, Ag. (*Jurassic and Cretaceous.*)

8. **"Les Pectinacees,"** Agassiz.

Shell short, oval subtrigonal; without a distinct corselet; surface ornamented with concentric radiating costæ.

Type.—T. pectinata, Lamk. (*Existing seas.*)

These groups, it will be observed, are founded upon differences of form and ornamentation analogous to those presented in the *Unionidæ*, where they appear to be coincident with differences of structure in the animal, considered by Prof. Agassiz of generic value. It does not, however, necessarily follow from this, even if we admit all the proposed genera of *Unionidæ*, that the sections of *Trigonia* under consideration must be viewed as distinct genera; since the differences of form and structure observed in the various groups, and subordinate divisions of the animal kingdom, are so infinite and varied, that we cannot always apply precisely the same rules for the distinction of genera in one family, that serve to distinguish those of another.

The genus *Trigonia* is closely related to *Myophoria*, of Bronn, by which it seems to have been represented, during the Triassic epoch, as the latter was represented during the deposition of the Permian and older rocks, by the genus *Schizodus*, of King. For remarks on the relations of these three groups, see pages 57 and 58.

If we exclude *Myophoria* from the genus *Trigonia*, it will probably be found to range back no farther than about the commencement of the Jurassic epoch, towards the middle of which it seems to have nearly or quite attained its maximum development.[1] It was also well represented during the deposition of the Cretaceous rocks, but appears to have become almost extinct at the close of that epoch, since only a few doubtful instances of its occurrence in Tertiary deposits have been recorded. Some five or six species, however, are known to be still living in the Australian seas.

Trigonia Conradi.

(Plate iii, Fig. 11.)

Trigonia Conradi, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 183.
Trigonia Conradi, Meek & Hayden, " " " " " Oct. 1860, 418.

Shell rather small, short, subtrigonal, moderately compressed; anterior side truncate; base rounded; posterior side sloping obliquely from the beaks above, and apparently vertically truncate at the immediate extremity. Beaks elevated, narrow, incurved, and located in advance of the middle; posterior umbonal slopes rather distinctly

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[1] A few of the Saint Cassian (Triassic?) species may possibly belong to some section of the genus *Trigonia.*

angular. Surface ornamented by small, simple, obscure concentric costæ, which on the posterior side of the valves descend at first perpendicularly, after which they are deflected forward parallel to the basal and anterior borders.

Length and height, each about 0.97 inch; convexity, 0.58 inch.

The specimens of this species we have seen, are not in a condition to have retained fine surface markings if there were any; nor do they show very satisfactorily the character of the corselet, though it seems to have been marked by obscure radiating costæ, and is bounded on each side by the distinctly angular umbonal slopes. The specific name was given in honor of Mr. T. A. Conrad, the well-known Palæontologist of Philadelphia.

Locality and position.—Southwest base of the Black Hills; in the lower Jurassic beds of that region. (Type No. 212.)

Family MYTILIDÆ.

Shell inequivalve, inequilateral, closed, elongate, oval or oblong; covered with a thick dark epidermis; interior more or less pearly; ligament internal or submarginal, very long; hinge nearly or quite edentulous, or sometimes crenate. Posterior muscular impression large, and faintly marked; anterior generally small. Pallial line simple.

Animal with mantle margins free, or united behind so as to form a more or less complete anal tube; labial palpi elongated, pointed, and free; gills two on each side, elongated, nearly equal, united to each other behind, and to the mantle. Foot cylindrical, grooved, and byssiferous.

This group includes the following genera, viz.: *Mytilus*, *Volsella*, *Pachymya*, *Lithophagus*, *Myrina*, *Adula*, *Crenella*, *Hippagus*,[1] and *Stalagmium*.[2]

Messrs. H. and A. Adams divide it into the following subfamilies, viz.:—

1. *Mytilinæ*. Hinder part of mantle but slightly produced; anterior muscular scar generally small. Including *Mytilus*, and *Myrina*.
2. *Crenellinæ*. Hinder part of mantle produced so as to form false siphons. Includes *Crenella*, *Volsella*, and *Adula*.
3. *Lithophaginæ*. Hinder part of mantle more or less produced; anterior adductor muscle moderate. Includes *Lithophagus*.

The fossil genera *Pachymya*, *Modiolopsis*, and a part of species referred to *Orthonota*, seem to belong to this family; but as we know them only as extinct species, it is scarcely possible to determine to what particular section of the group they most properly belong.

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[1] Chenu (in Man. de Conch. II, p. 169) places *Hippagus*, Lea, in the family *Trigoniidæ*, and figures Wood's sp. *verticodius*, as a cretaceous example of that genus. This, however, is far from correct, that species being the type of the genus *Verticordia* and a *Miocene* shell; while *Hippagus isocardoides*, Lea, a widely distinct form, from the Eocene, is the type of *Hippagus*, and belongs, as we think, to the *Mytilidæ*, very near the genus *Crenella*, if it is indeed even generically distinct.

[2] If *Nucunella*, and *Nuculocardia*, D'Orbigny, are distinct from *Stalagmium*, they should apparently be placed at least near that group in the *Mytilidæ*. Chenu, in the work above cited (p. 181), places *Nucunella* in the *Arcidæ*, and figures its type, *N. Nystii*, both there and on p. 153, under *Crenella*, in the *Mytilidæ*.

Genus VOLSELLA, Scopoli.[1]

Synon.—*Volsella*, Scopoli, Intr. Hist. Nat. 1777, 397.—Modeer, K. Vet. Ac. Handl. 1793, 392.—Gray, Proceed. Zool. Soc. Lond. 1847, 197.
Tamarindiformis, Meusch. (part), Mus. Gerves, 1787, 412.
Callistriche and *Callistrichoderma* (sp.), Poli, Utr. Sic. I, 1791, 194.
Modiolus, Lamk. Prodr. 1799, 87.—Cuvier, Anat. Comp. 1800; Regne An. II, 1817, 471; and ib. III, 1830, 136.—Link, Rost. Samml. III, 1807, 146.—Goldf. Zool. 1820, 611.—Risso, Hist. IV, 1826, 323.—Forbes, Mal. Mon. 1838, 43, &c.
Modiola, Lamk. Syst. An. 1801, 113; Id. An. du Mus. VI, 1805, 119; and Hist. VI, 1819, 109.—Feruss. Tab. Syst. 1821, p. xlii.—Blainv. ("*Modiole*"), Dict. Sci. Nat. XXXII, 1824, 318.—Bronn, Leth. 1837, 355, &c. &c.
Amygdalum, Muhlf. Entw. 1811, 69.
Mytilus (sp.), Schum. Essai, 1817, 106, and various others.
Brachyodontes, Swainson, Malacol. 1840, 384.
Etym.—*Volsella*, a kind of forceps or tweezers.
Type.—*Mytilus modiolus*, Linn.

Shell transversely oblong; surface smooth, concentrically striate, or with radiating or divaricating striæ or costæ; epidermis often produced into long filaments. Beaks depressed, and placed near the anterior extremity. Hinge sometimes a little callous and crenated, but without proper teeth; ligament linear, occupying a marginal groove. Muscular impressions very unequal; pallial line faintly marked.

Animal with mantle margins open, plain, protruding in the branchial region; anal tubes short, more or less complete; palpi triangular; byssus fine and strong.

This genus, as here defined, embraces two sections or subgenera: 1. The typical species, with a smooth or striate surface, and a non-crenated hinge; 2. Species with radiating or divaricating costæ or striæ, and a crenated hinge-margin (*Brachydontes*, Swains.). *Adula*, of H. & A. Adams, is also sometimes included as a third section, but it seems to be sufficiently distinct to rank as a separate genus.

The genus *Volsella*, or *Modiolus*, is nearly related to *Mytilus*, but differs in having the beaks obtuse and placed more or less back from the anterior end, instead of being pointed and quite terminal. The antero-basal region of these shells is also always more prominent than in the *Mytili*. There are likewise some differences in the habits of these two genera.

Species have been referred to this genus from the Silurian rocks, but they doubtless all belong to *Modiolopsis*, *Orthonota*, and other extinct genera.

Several species presenting the external appearance of *Volsella* have also been described from the Devonian and Carboniferous rocks, but we yet want a more accurate knowledge of their hinge and interior, before we can be quite sure they are true Volsellas. The genus seems to be represented in the Triassic rocks, and its existence during the deposition of the Jurassic system of strata is well known. It

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[1] Scopoli's first species of *Volsella* was *Mytilus modiolus*, Lin., the type of the subsequently proposed genus *Modiolus*, or *Modiola*, of Lamk.; while the others belong to the older genus *Mytilus* proper, of Lin. As Scopoli was a strictly binomial author, however, the law of priority compels us to adopt his name for the previously unnamed group, of which *Mytilus modiolus*, Lin., is the type. For a *regularly* proposed name cannot be wholly ignored, because the author happened to include some species belonging to an older genus.

also occurs in the Cretaceous and Tertiary deposits, and is abundantly represented in our existing seas, where it probably attains its maximum development. The recent species are chiefly found in southern latitudes, though a few occur on the coast of Great Britain, and in the Mediterranean and Arctic seas; also on the eastern coast of the United States, &c.

Volsella pertenuis.

(Plate III, Fig. 5, 5*a*.)

Mytilus pertenuis, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. March, 1858, 51.
Comp. *Modiola minuta*, Quenstedt, Der Jura, tab. i, fig. 36.
Volsella pertenuis, Meek, Smithsonian Check List N. Am. Jurass. Foss. 1864, 28.

Shell small, very thin and fragile, narrow oblong-oval, slightly arcuate; valves convex along the middle, from near the beaks obliquely backward, in the direction of the lower part of the posterior end. Extremities narrowly rounded, the anal end being a little broader than the other; base slightly arched behind the middle. Hinge nearly straight, and apparently rather less than half the length of the shell; dorsal margin forming a broad descending curve from the back extremity of the hinge posteriorly. Beaks small, subangular, and located at the anterior end, scarcely projecting beyond the margin. Surface marked by fine, rather obscure, lines of growth.

Length, 0.73 inch; breadth, 0.26 inch; height, 0.30 inch.

This shell is so very similar to a Jurassic species figured by Quenstedt (Der Jura, tab. i, fig. 36), under the name of *Modiola minuta*, that, after further comparisons, we are at a loss to point out any characters by which it can be distinguished. As there seems, however, to be some reason to doubt the identity of the shell figured by Quenstedt with *M. minuta* of other authors, we have concluded to retain our name, *pertenuis*, until authentic specimens of these shells can be compared.

The species now under consideration is also similar in form to young specimens of *Mytilus Meekii*, Evans & Shumard (Trans. St. Louis Acad. Sci. vol. i, p. 40), but is shorter in proportion to its height. The fact, too, that *M. Meekii* is an upper Cretaceous species, while that now before us occurs in rocks holding a rather low position in the Jurassic system, is conclusive evidence, we think, that they must differ specifically.

If Adanson's ante-Linnæan genera are to be adopted, with his first species of each as its type, the name of our shell would have to be written *Perna pertenuis*, as it belongs to the same group as the type of *Perna*, of that author (not of Brug., Oken, or Cuv.). If, on the contrary, neither *Perna*, Adanson, nor *Volsella*, Scopoli, should be retained, we must adopt *Modiolus*, Lamarck, and call it *Modiolus pertenuis.*

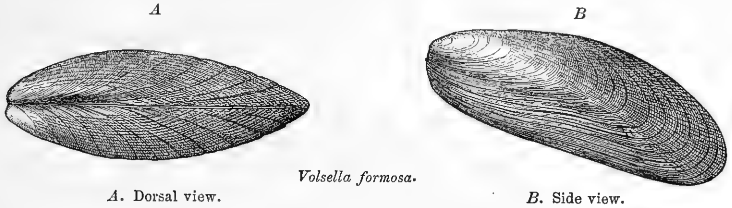
Locality and position.—Southwest base of the Black Hills, in the lower Jurassic of that region. (Type 215.)

Volsella formosa.

Modiola (*Perna*) *formosa*, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1861, 439.
Volsella formosa, Meek, Smithsonian Check List N. Am. Jurass. Fossils, 1864, 28.

Shell elongate-subelliptical, a little arcuate, gibbous along the oblique umbonal slopes, from the beaks to the postero-basal extremity; greatest convexity near the middle of the valves. Ventral margin somewhat sinuous near the middle, or a little behind it, and rounding up rather abruptly at the extremities; dorsal outline broadly arcuate, declining from the middle posteriorly; both extremities rather narrowly rounded. Beaks small, somewhat compressed, obtuse, and located directly over the anterior margin, beyond the outline of which they scarcely project. Surface ornamented with small concentric striæ, and a few stronger marks of growth, which are crossed on the dorsal and postero-dorsal regions, by regular, closely arranged, and generally simple radiating lines. Faint traces of another system of extremely fine striæ may be also sometimes seen by the aid of a magnifier, crossing the somewhat compressed ventral region of the valves, from the oblique umbonal ridge, nearly at right angles to basal margin.

Length, 2.05 inches; diameter from the dorsal margins, at right angles to the length, near the middle of the shell, 0.34 inch; greatest convexity at the same point, 0.80 inch.



Volsella formosa.

A. Dorsal view. *B.* Side view.

This species belongs to the irregularly proposed genus *Perna*, Adanson, = *Modiolus*, Lamarck, and will fall into Swainson's section *Brachyodontes.* It seems to be very closely related to the European *Volsella cancellata* (= *Mytilus cancellatus*, Goldfuss, Petref. Germ. tome ii, pl. 131, fig. 2), and may possibly prove to be identical, when we can have an opportunity to compare a good series of each. The five or six specimens, however, of the form here described, that we have seen, all present the following differences from Goldfuss' figure: In the first place they are narrower from the dorsal to the ventral margins, more narrowly rounded at the posterior extremity, and have slightly more prominent beaks; while their antero-ventral region is a little more convex, and their basal outline more arcuate. The surface markings of the species under consideration are very similar to those of Goldfuss' species, though his enlarged figure represents the concentric striæ crossing the radiating lines as being more distinct and regular than on our shell. Again, he neither figures, nor mentions in his description, the fine obscure transverse striæ seen on the ventral half of our species, though these are so indistinct that they might be easily overlooked; indeed they seem to be rather dependent, in some way, upon the structure of the shell, than properly surface markings.

We observe D'Orbigny cites *Modiola cancellata*, of Roemer, and his own *M. Strajeskiana*, from the Jura of Russia, as synonymous with *Mytilus cancellatus*, Goldfuss. Without knowing to what extent Goldfuss' species may vary, we cannot feel prepared to express a positive opinion in regard to its relations to the forms named by Roemer and D'Orbigny; though judging by their figures, we would be inclined to doubt the identity of these shells. At any rate, Roemer's and D'Orbigny's figures are very unlike the form now before us, which is remarkably uniform in its characters.

Locality and position.—From the Jurassic beds of Big Horn Mountains, Dakota Territory. (Type 1882.)

FAMILY ARCIDÆ.

Shell equivalve or subequivalve, not pearly within, closed or gaping below, usually gibbous; surface frequently ornamented with radiating costæ or striæ. Hinge straight or arched; provided with a more or less elongated posterior and anterior lateral tooth, which are divided transversely, obliquely, or longitudinally, into small interlocking, short, or linear plates. Ligament external, attached to a more or less developed cardinal area; cartilage occupying a series of small marginal pits (usually leaving linear grooves in the area as the shell advances in its growth), or very rarely collected within a single larger central cavity. Muscular impressions two; pallial line simple.

Animal without siphons or true palpi; mantle margins open, simple or fringed, often provided with ocelli; labia formed of the extremities of the branchiæ; gills oblique or pendent, separated behind, or united to a membranaceous septum; foot large, bent, generally grooved, and with plain or crimped margins.

As was first observed by Dr. Gray, the hinge in this and some allied families, although in most cases apparently provided with a numerous series of small teeth, has really but a posterior and an anterior tooth, which are divided vertically, obliquely, or horizontally into small, more or less numerous interlocking plates. These divisions, Dr. Gray thinks, are analogous to the transverse ridges produced by the striæ or furrows in the teeth of *Trigonia.* In the typical Arks (that is, viewing *A. Noœ* as the type), and some of the other genera, the divisions of the teeth cut the hinge margin nearly or quite at right angles, but they are found to become more and more oblique, as we pass from group to group, until in *Cucullœa*, *Macrodon*, &c., they range, particularly behind the beaks, parallel to the cardinal margin.

The family *Arcidœ*, including the various fossil and recent genera, seems to embrace three, and possibly four, more or less marked subfamilies, distinguished mainly by the arrangement of the cardinal plates, and partly by the general form and obliquity of the shell, &c. These subfamilies may be arranged and characterized as follows:—

1. Arcinæ.

Shell more or less oblong, or subrhombic; umbonal axis oblique, hinge margin straight or more or less arched; cardinal plates crossing the hinge margin at various angles, or rarely dividing it horizontally near each extremity.

Includes *Arca, Barbatia, Striarca, Anadara, Senilia, Lunarca, Argina, Noetia, Litharca, Parallelepipedum, Scaphula, Cucullæa,* and probably *Isoarca?* and several undefined fossil genera. (*Palæozoic?* to *modern seas.*)

2. Macrodontinæ.

Form, hinge line, and umbonal axis, generally much as in the *Arcinæ.* Anterior hinge plates crossing the cardinal margin obliquely forward and upward; posterior plates ranging parallel to the hinge line, often long and linear; mesial plates obsolete.

Includes *Macrodon, Grammatodon, Cypricarditis,* and probably *Vanuxemia,*[1] *Megalomus, Megambonia, Dolabra,* and some undefined genera. (*Palæozoic* to *Jurassic.*)

3. Axininæ.

(*a.*) Shell orbicular, or suborbicular; cartilage as in *Arcinæ;* umbonal axis nearly vertical; hinge line regularly arched; cardinal plates short, and arranged as if radiating from an imaginary point below the hinge. Includes *Axinæa.*

(*b.*) Form and hinge as in subsection (*a.*). Cartilage occupying a single pit at the middle of the hinge. Includes *Limopsis.*

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[1] If *Megalomus*, Hall, 1852, *Vanuxemia*, Billings, 1858, and *Megambonia*, Hall, 1859, are, as is thought to be the case, all synonymous, then the rules of priority would compel us to adopt the name *Megalomus* for the group. Until the relations of these proposed groups have been more clearly determined, it is probably better to retain them all, provisionally, as distinct genera.

We are aware these divisions are not equally distinct, the *Macrodontinæ* and *Arcinæ* being more nearly related through *Cucullæa*, *Scaphula*, &c., than either of these groups is to the *Axininæ.* Still, we find the Jurassic group *Macrodon* shading off so gradually through *Grammatodon*, *Dolabra*, *Cypricardites*, &c., to *Vanuxemia*, and other Palæozoic groups—some of which depart so widely from the recent Arks as to be scarcely recognized as belonging to the same family—that these forms seem to stand together as a distinct subfamily. At a first glance it might be thought the genus *Cucullæa* should be included in the *Macrodontinæ;* but on a closer inspection, it will be observed that in that genus the hinge always differs from these older groups, in never having the anterior hinge plates ranging obliquely forward and upwards, and at the same time the posterior ranging parallel to the hinge line. Again, the posterior hinge plates are never so disproportionally elongated in *Cucullæa* as in the older groups, while it also differs in having small vertical, mesial plates or denticles between the posterior and anterior divisions. At the same time that these differences exist between the genus *Cucullæa*, and all the allied genera included in the subfamily *Macrodontinæ*, *Cucullæa* is found to be connected by such an unbroken series, through various fossil and recent forms, with the typical *Arcinæ*, that it seems unnatural to separate it and the most nearly allied genera into a distinct subfamily.

SUBFAMILY MACRODONTINÆ.

Genus GRAMMATODON, MEEK & HAYDEN.

Synon.—*Cucullæa* (sp.), QUENSTEDT, Der Jura, 1856.
Arca (*Cucullæa*) sp. MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. March, 1858, 51.
Grammatodon, MEEK & HAYDEN, ib. Oct. 1858, 419.
Etym.—γϱομμή, a line; ὀδὼν, a tooth, in allusion to the linear teeth.
Type.—*Arca* (*Cucullæa*) *inornata*, MEEK & HAYDEN.

Animal unknown. Shell longitudinally oblong, or rhombic oval, nearly or quite equivalve, inequilateral; valves rather gibbous, and without crenulated margins; umbones somewhat depressed, incurved, and not very widely separated. Ligament area rather narrow; hinge straight, provided in each valve with a few elongated, linear posterior cardinal plates, arranged parallel to the hinge margin; and a greater number of shorter, oblique anterior plates in front of the beaks. Pallial line obscure; muscular impressions faintly marked, and without a projecting lamina or ridge. Surface nearly smooth, or with obscure radiating costæ or striæ.

The species upon which we propose to found this genus agrees almost exactly, in the character of its hinge, with *Macrodon* of Lycett; but is proportionally much shorter, and differs in having its pallial margin smooth, and closed, instead of crenulated and gaping. Its beaks are also located farther back, while its muscular impressions differ in being destitute of any ridge or prominence, such as we see in *Macrodon* and *Cucullæa.* Possibly it may be only a subgenus under *Macrodon.*

It is but necessary, we think, to compare the hinge of such forms as these with that of the recent *Arca Noæ*, usually regarded as the type of the genus *Arca*, to be satisfied that they cannot be included in the same group, in accordance with correct rules of classification.

The group under consideration will probably include several other Jurassic, and possibly a few Cretaceous species, though we cannot, with any degree of confidence, attempt to define its exact geological range.

Grammatodon inornatus.

(Plate III, Fig. 9, 9*a*, 9*b*.)

Arca (Cucullæa) inornata, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. March, 1858, 51.
Grammatodon inornatus, Meek & Hayden, Ib. Oct. 1862, 419.
Comp. *Cucullæa Munsteri* (Zeiten), Quenstedt, Der Jura, tab. 13, fig. 38; tab. 18, fig. 34; tab. 23, fig. 8.

Shell subrhomboidal, or oblong-oval in outline, rather gibbous in the umbonal region. Anterior end rounding up from below, and forming an angle of about ninety degrees with the hinge line above; posterior side a little broader than the other, obliquely truncate above, and somewhat narrowly rounded below; base nearly straight along the middle, but not exactly parallel to the hinge line, rounding up more gradually in front than behind. Beaks rising somewhat above the hinge, incurved, and very slightly oblique, located a little in advance of the middle; posterior umbonal slopes prominently rounded. Hinge comparatively long, but not quite equalling the greatest length of the shell; posterior hinge-plates three or four in each valve; anterior much shorter, and usually numbering about six or seven. Ligament area not very broad. Surface apparently smooth.

Length, 0.75 inch; height, 0.45 inch; breadth, 0.46 inch.

Quenstedt figures several forms similar to this under the name of *Cucullæa Munsteri*, in his "Der Jura," though none of them appear to agree exactly with our shell. The true *C. Munsteri*, as figured by Goldfuss (Petrefact. Germ. tab. 122, fig. 10), differs, at least from our species, in having a rather distinct ridge along the cardinal margin. All of our specimens also appear to be entirely destitute of radiating striæ; though there may be very fine radiating lines, where the surface is well preserved.

Locality and position.—Southwest base of Black Hills, associated with other Jurassic fossils. (Type 201.)

Family UNIONIDÆ.

Shell equivalve, inequilateral, regular, smooth, plicate or tuberculate, nacreous within; epidermis thick, covering a prismatic cellular layer; margins closed and smooth within; ligament external. Hinge varying with the genera and subordinate groups. Muscular impressions deep; pedal scars three in each valve, two behind the anterior adductor, and one before the posterior; pallial line simple.

Animal with mantle margins disconnected, excepting between the anal and branchial regions; not produced into siphonal tubes, but fringed in the branchial, and usually plain in the anal regions. Foot very thick, tongue-shaped, often byssiferous in the young, but rarely so in the adult. Gills elongate, subequal, free or connected with the mantle or abdominal sack behind. Labial palpi usually united behind.

Conchologists differ very widely in regard to the number of generic and subgeneric heads under which the numerous species included in this family should be arranged. The following are the names of the genera most usually admitted by late writers, viz.: *Unio*, *Anodonta*, *Byssanodonta*, *Margaritana*, *Monocondyllæa*, and *Barbala*. Prof. Agassiz, however, who has dissected, with much care, many of our American species, finds that they present marked differences in the arrangement of the gills, and the position of the eggs in the same, as well as in other anatomical details, from which he is led to the conclusion that there are at least twenty-two distinct genera amongst our species usually referred to *Unio*, *Anodonta*, *Alasmodonta*, and *Margaritana*. For these groups he has adopted the following names, viz.: *Dysnomia*, Ag.; *Scalenaria* (Raf.), Ag.; *Truncilla* (Raf.), Ag.; *Lampsilis*, Raf.; *Canthyria*, Swainson; *Eurynia*, Raf.; *Metaptera*, Raf.; *Alasmodonta*, Say; *Obovaria*, Raf.; *Micromya*, Ag.; *Cyprogenia*, Ag.; *Plagiola*, Raf.; *Orthonymus*, Ag.; *Tritogonia*, Ag.; *Quadrula*, Raf.; *Rotundaria*, Raf.; *Complanaria*, Swainson; *Pleurobema*, Raf.; *Uniopsis*, Swainson; *Margaritana*, Schumacher; *Hemilasterna*, Raf., and *Unio*, Retz.[1]

Mr. T. A. Conrad, of Philadelphia, who admits many of these groups as subgenera under *Unio*, also proposes to adopt the following additional subgenera, mainly for the reception of foreign species, viz.: *Nodularia*, Con.; *Iridea*, Swainson; *Mysca*, Turton; *Lanceolaria*, Con.; *Cœlatura*, Con.; *Cunicula* (Sw.), Con.; *Glebula*, Con.; *Uniomerus*, Con., and *Theliderma*, Swainson. The following he proposes as full genera: *Cucumaria*, Con.; *Hyriopsis*, Con., and *Monodontina*, Con.

As an example of the widely different views entertained by authors in regard to the classification of these mollusks, we should remark that Dr. Isaac Lea, who has given more attention to the study of the *Unionidæ* than perhaps any other person, includes the whole, along with some others not generally admitted in this family, under two generic heads, for which he adopts the names *Margaron* and *Platiris*. Under the first of these he ranges as subgenera, *Triquetra*, *Prisodon*, *Unio*, *Margaritana*, *Monocondylæa*, *Anodonta*, and *Dipsas*, ; and under the second *Iridina*, *Spatha*, and *Mycetopus*.[2]

Mr. Niclin went still farther in this direction, and included *Unio*, *Anodonta*, *Alasmodonta*, *Iridina*, *Dipsas*, *Hyria*, and *Castalia* as members of a single genus![3]

The family *Unionidæ* has a wide geographical distribution, but is most numerously represented in the streams of North America. Although apparently represented as far back as the Jurassic period, it is pre-eminently characteristic of the present epoch, since the species and genera are far more numerous now than they were during any of the past geological periods. The existing species also present much greater diversities of form and ornamentation, and sometimes attain larger sizes than are known to occur amongst those now extinct.

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[1] Weigmann's Arch. 1852, p. 41.

[2] Synopsis Naïdes, 3d ed. Phila. 1852.

[3] Trans. Phil. Soc. VIII, p. 398.

Genus UNIO, Retzius.

Synon.[1]—*Unio*, Retz. Diss. Phys. 1788, 16.—Brug. Jour. d'Hist. Nat. 1792, and Encyc. Méth. I, tab. 247.—Cuv. Tab. Elem. 427.—Lamk. Prod. 1799, 87, and Syst. 1801, 114.
Mya, Humphrey, Mus. Coll. 1797, 59 (not Linn.).
Limnium, Oken, Lehrb. d. Naturg. III, 1815, and 1821, Naturg. f. Schul. 651, 8.
Ellipto, Raf. Jour. Phys. tom. 88, 1819, 426, and 1820 Monogr. Bivalves of the Ohio. . . .
Margarita (part), Lea, Trans. Am. Phila. Soc. VI (n. s.), 1 (not Leach, 1819).
Cunicula, Swainson, Malac. 1840, 267, and 378.
Margaron (part), Lea, Synop. Naid. (3d ed.), 1852, p. xvii.
Etym.—*Unio*, a pearl.
Type.—*Mya pectorum*, Linn.

Shell variable in form, usually oval, elongate or oblong; surface covered with a brownish or olivaceous epidermis, sometimes striped with greenish and olive bands. Beaks often eroded. Nacre white, yellowish, flesh-colored, or purple. Hinge variable, generally with two anterior teeth in one valve, and one in the other, or two in each; posterior teeth elongate and laminar, usually two in one valve and one in the other.

Animal, in the typical species, with gills free from the abdominal sac, their posterior extremity attached to the mantle; eggs in the female filling the whole extent of the outer gill; mantle fringed at both syphonal openings. (Agassiz.)

As above restricted, it will be rather difficult to determine the geological range of the genus *Unio*, since some of its more important distinctive characters are such as belong to the softer parts of the animal only. The oldest known species apparently belonging to this genus have been described from the Jurassic rocks, though it is somewhat doubtful whether these are true Uniones. It was formerly supposed that some Carboniferous and Devonian shells belonged to this genus, but they are now all known to belong to *Cardinia*, *Carbonocola*, and other extinct groups. Several species apparently presenting the characters of this group have been described from the Wealden beds, but this type of life seems not to have been very generally distributed over the world until the Tertiary epoch; and it undoubtedly attains its greatest development at the present time, and in the streams of this country. (Type 192.)

Unio nucalis.

(Plate III, Fig. 13, *a*, *b*, *c*.)

Unio nucalis, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. March, 1858, p. 52.

Shell longitudinally oval, gibbous in the central and umbonal regions. Anterior extremity rather narrowly rounded; base semi-oval, sometimes rather prominent near the middle; posterior end subtruncate, or forming a regular curve from above, and rather narrowly rounded below. Beaks moderately depressed, located about half way between the middle and the anterior end, not eroded; posterior umbonal slopes prominently rounded. Surface marked by fine obscure concentric lines, and more or less distinct marks of growth; the latter becoming small, and very regular wrinkles on the beaks.

Length, about 1.63 inch; height, 1.05 inch; breadth, 0.82 inch.

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[1] A number of the names mentioned in connection with the family *Unionidæ* are doubtless only synonyms of *Unio;* but until the limits of this genus have been more satisfactorily determined, it is probably better to include only those more exactly synonymous with the genus as restricted to the typical forms.

Although apparently associated with an *Ammonite* (*A. Henryi*), and a small *Ostrea*, this shell seems to present, as far as we have been able to see, the characters of a true *Unio.* We are the more inclined to regard it as belonging to that genus, in consequence of the fact that we also find in the same matrix a small *Planorbis*, and apparently a *Valvata*, and a *Viviparus.* None of our specimens show the hinge very satisfactorily, though in one left valve (Pl. III, Fig. 13, *c.*) it is seen to be rather thick, a little arched, and provided with a long, posterior lateral tooth, extended parallel to the cardinal margin, from which it is separated by a deep groove, for the reception of a similar tooth in the other valve. The anterior tooth is compressed, irregular, somewhat corrugated, and located nearly under the beaks; while the ligament is in all respects apparently similar, in form and position, to that of our recent Uniones.

Specimens having the surface well preserved sometimes show very small, radiating wrinkles on the posterior side of the umbones, near the hinge; in most cases, however, these are obsolete. A small, obscure, linear ridge is also generally seen extending from the back part of each beak obliquely backward and downward, just within the prominent umbonal slopes. The minute concentric wrinkles are very regular on the beaks.

The specimens of this species we have seen were not broken directly from the rock in place, but from the composition, color, &c. of the matrix, and the circumstances under which they were found, we are led to think they occur in a Jurassic bed seen at the locality where they were found, though we are not positively satisfied they may not be Cretaceous or Tertiary species. They differ, however, specifically from any of the forms yet known in these rocks in the northwest.

Locality and position.—Southwest base Black Hills. Jurassic. (Type 196.)

FAMILY CRASSATELLIDÆ. (See page 34.)

Genus ASTARTE, SOWERBY.

Synon.—*Astarte*, J. SOWERBY, Min. Conch. II, 1816, tab. 137.—LAJONKAIRE, Monogr. in Mém. Soc. de Hist. Nat. de Par. I, 1823, 129.—FLEMING, Brit. An. 1828, 409.—RANG. Man. 1829, 314.—DESHAYES, Encyc. Meth. II, 1830, 76; III, 553.—SCACCHI, Osservaz. Zoolog. 1833, No. 2.—BRONN, Leth, 1837, 374.
Tridonta, SCHUM. Essai, 1817, 146.—MOLLER, Isis, 1832, 135.
Crassina, LAMK. Hist. Nat. V, 1818, 554.—FERUSSAC, tab. Syst. 1821, p. xlii.—SCHWEIGG, Natgsch. 1820, 710.—BLAINV. Malacol. 1825, 557.
Nicania, LEACH, Jour. Phys. I, 1819, 88, 465.—BLAINV. Malacol. 1825, 558.
? *Goodallia*, TURTON, Brit. Bivalves, 1822, 77.—FLEMING, Brit. An. 1828, 409 and 429.—FORBES, Malac. 1838, 48.
Mactrina, BROWN, Brit. Conch. 1827, tab. xvi; and Conch. Text-Book, 1833 (VI ed. 159).
Etym. — *Astarte*, the Syrian Venus.
Examp.—*Venus Danmoniensis*, MONT.

Shell oval, subtrigonal, or suborbicular, thick, usually compressed, closed. Surface smooth, or marked with concentric striæ or undulations; ligament external; lunule generally well defined. Hinge with two strong diverging primary teeth in one valve, and one or two in the other. Impressions of the adductor and pedal muscles deep and well defined; pallial line simple.

A few species have been referred to this genus from Devonian and Carboniferous rocks, but too little is known in regard to the hinge and interior of these shells to warrant the conclusion that they are beyond doubt true Astartes. Two species, described by Prof. King, from the Permian rocks of England, possess the external characters of this genus, and one of them, at least (*A. Vallisneriana*), as since figured by Prof. Geinitz (Dyas. Pl. 12, figs. 24 and 25), seems also to present the dentition of the Astartes.

From the Trias, Prof. F. M. Roemer has described three species of *Astarte*, and several are known from the Liassic rocks. In the later members of the Jurassic system, particularly in the Oolites, the species are quite numerous. The genus also ranges through the succeeding formations, and probably reached its greatest development during deposition of the Tertiary rocks. It is, however, well represented in the seas of the existing epoch. The recent species are usually found in northern latitudes. They occur on the shores of North America, Northern Europe, Norway, Greenland, &c.

Astarte fragilis.

(Plate iv. Fig. 7.)

Astarte fragilis, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 183.

Shell small, rather broad oval, thin, moderately compressed. Anterior end rounded; base nearly straight along the middle, rounding up regularly in front, and more abruptly behind; posterior extremity obscurely subtruncate; dorsum straight and slightly declining behind the beaks, which are small, obtuse, rather depressed, and located a little in advance of the middle. Posterior umbonal slopes prominent. Surface ornamented by distinct, irregular concentric wrinkles, and fine parallel striæ. (Hinge and interior unknown.) Pallial margins crenulate.

Length, 0.45 inch; height, 0.32 inch; breadth, about 0.18 inch.

The rather unusual thinness and oval form of this little shell lead us to doubt whether it can be a true *Astarte*, though even in this respect, as well as in its other characters, it is evidently quite similar to some Jurassic forms generally placed in that genus.

In several respects it resembles quite closely the small thin variety of *A. excavata*, Sowerby sp., figured by Morris and Lycett in their monograph of the English Oolitic fossils, pl. 9, fig. 19 (Palæont. Soc.), but its beaks are located further back, and its posterior margin is narrower and more oblique; while its lunule does not seem to be excavated as in that species.

Locality and position.—Southwest base of the Black Hills, in the lower Jurassic beds of that region. (No. 194.)

Astarte inornata.

(Plate III, Fig. 12, *a*, *b*.)

Astarte inornata, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 183.

Shell subelliptical, compressed; extremities rounded, the posterior margin forming a broader curve than the other. Base semi-elliptical in outline; dorsum declining from the beaks, the anterior slope being a little concave, and the other nearly straight, or slightly convex. Beaks moderately elevated, compressed, located just in advance of the middle. Lunule rather deep, lance-oval, bounded on each side by a more or less distinct angle. Surface marked by concentric striæ, with a tendency to develop small, very obscure concentric wrinkles.

Length, 1.15 inch; height, 0.79 inch; breadth, about 0.44 inch.

We only place this shell in the genus *Astarte* from its similarity to several Jurassic species of that group, not having seen its hinge or interior.

Locality and position.—Same as last. (No. 202.)

FAMILY TANCREDIIDÆ.

Shell oval-subtrigonal, longer than high, never very gibbous, equivalve, subequilateral, nearly smooth; valves gaping or closed; hinge with cardinal, and usually posterior lateral teeth; muscular impressions moderate, smooth; pallial line simple; ligament external, or probably sometimes partly internal.

Animal unknown.

The genus *Tancredia* presents a combination of characters that seem to forbid its admission into any of the established families of *Lamellibrarchiata.* Until the affinities of this and some little known fossil shells, apparently not more than generically separated from it, can be better determined, it has been thought preferable to propose a distinct family for their reception. It is perhaps most nearly related to the *Cardiidæ* (in which some authors place it) than to any other family, though the more elongate, compressed, Donaciform outline and smooth surface of these shells give them a peculiar physiognomy, very unlike any of the genera known to belong to that family; while some of the closely related fossil forms belonging apparently to one or more undescribed genera are known to be distinctly gaping in front, as well as behind, a feature unknown in the *Cardiidæ.*

Their simple pallial line, and external ligament, would exclude these shells from the *Mactridæ*, which they resemble in form; while the former of these characters shows that they cannot be placed in the *Tellinidæ.* Their general physiognomy, not less than their comparatively small, smooth muscular scars, show that they cannot be properly included in the *Lucinidæ*, to which they are often referred.

This family, in addition to the typical genus, includes the recently proposed genus *Meekia*, of the Cretaceous rocks of California.

Genus TANCREDIA, LYCETT.

Synon.—*Donax*, *Mactra*, &c. (sp.) of DUNKER, DESHAYES, D'ORBIGNY, and others.
Tancredia, LYCETT, Ann. Mag. Nat. Hist. vi, 1850, 407.—MORRIS and LYCETT, Moll. Great Oolite, 1853, 90.
Hettangia, TERQUEM.—BUVIGNIER, Statist. Geol. Mineral. et Palæont. du Dept. de la Mus. 1852, Atlas, 14.—TERQUEM, Bul. Soc. Geol. Fr. tom. 10 (2è sér.), 1853, 364.
Etym.—Dedicated to Sir Thomas Tancred.
Type.—*Tancredia donaciformis*, LYCETT.

Shell depressed subtrigonal, or longitudinally subovate, rather compressed, without a defined lunule; basal margin semi-ovate or semi-elliptical in outline, not crenate within; posterior side wider and more convex than the other, sometimes gaping; anterior side more or less attenuate or pointed, and closed; beaks subcentral, usually small, contiguous; ligament short, external, occupying a small depression. Hinge with one obtuse cardinal tooth in each valve, fitting into a corresponding cavity in the other; sometimes a small accessory cardinal tooth at the anterior side of the cavity in the right valve, and on the posterior side in the left. Lateral teeth large, obtuse posterior, that of the left valve prominent, and fitting into a depression in the tooth or callosity of the other valve. Muscular impressions oval; the simple pallial line obscure, and remote from the margins. Margin of the right valve in front of the beaks, somewhat thickened, slightly projecting, and received into the margin of the other valve, though there are no proper anterior lateral teeth.

This genus dates back to the Liassic period; some ten or twelve species having been identified by M. Buvignier and M. Terquem, in rocks of that age, in France. So far as we are acquainted, it has not yet been recognized above this horizon on the continent, while in England it is only known in the lower Oolite. In America it ranges still higher, a single well-marked species having been described by us from Cretaceous beds, at the mouth of Judith River, on the Upper Missouri. In this country it also made its first appearance in Jurassic rocks.

This genus is closely allied to the Cretaceous genus *Meekia*, Gabb (Palaeont. California, I, 1864, 191), but differs in always having the anterior side closed instead of gaping, as well as less angular. There are also some differences in the hinge plate; while the ligament in Meekia is said to be only "subexternal."

Tancredia Warrenana.

(Plate III, Fig. 7.)

Tancredia Warrenana, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 183; ib. Oct. 1860, 418.

Shell small, trigonal ovate, moderately convex; anterior half a little narrower and more compressed than the other, narrowly rounded at the extremity; base forming a broad gentle curve; posterior side subtruncate, angular, or very abruptly rounded below. Dorsum sloping from the beak; the anterior slope being slightly concave in outline, and the other nearly straight, or a little convex. Beaks rather elevated, but not extending much above the cardinal edge; posterior umbonal slopes prominent or subangular. (Surface and hinge unknown.)

Length, 0.50 inch; height, 0.33 inch; breadth, about 0.14 inch.

We have not yet had an opportunity to see the hinge or the pallial line of this shell, and consequently only place it provisionally in the genus *Tancredia.* Its form, however, is such as to leave little room for doubt in regard to its relations to that group. As our specimens are casts, they do not give a very clear idea of the surface, though it seems to have been only marked by lines of growth. It is only the immediate extremity of the posterior margin that appears to be a little truncated vertically. Our specimens do not show whether the valves were gaping behind or not, but they have the appearance of being closed.

This species resembles more or less closely several of those figured by Morris and Lycett in their monograph of the fossils of the Great Oolite, but seems to differ specifically from them all, as well as from those figured by Terquem and other continental authors. It agrees most nearly in size and general appearance with *T. brevis*, Morris and Lycett (Mol. Gt. Oolite, part 3, fig. 8, pl. xiii, Palæont. Soc.), but is higher in proportion to its length, and more rounded at the extremities.

Locality and position.—Jurassic beds at southwest base of the Black Hills. (No. 204.)

Tancredia? æquilateralis.

(Plate III, Fig. 8.)

Tancredia? æquilateralis, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 183; ib. Oct. 1860, 418.

Shell very nearly elliptical, moderately convex; anterior end rather narrowly rounded; base forming a broad regular, semi-elliptic curve; posterior end slightly truncate on the upper oblique slope, narrowly rounded below, and apparently not gaping. Beaks depressed, located a little in advance of the middle. Surface of cast retaining traces of concentric striæ. (Hinge and interior unknown.)

Length, 1 inch; height, 0.64 inch; breadth, about 0.16 inch.

The specimens of this species in the collection are casts, in a rather soft yellowish sandstone, showing neither the hinge nor the muscular and pallial impressions Consequently we have no means of determining with much confidence to what genus it properly belongs. In form and general appearance it resembles some species of the above group, and the cast shows an impression behind the beaks, such as would be left by a posterior tooth or callus similar to that seen in many species of *Tancredia.*

Locality and position.—Jurassic beds at southwest base of the Black Hills. (No. 298.)

Family CARDIIDÆ.

Shell free, regular, equivalve, usually cordiform and gibbous; margins closed or gaping posteriorly, crenate or dentate within; surface generally with radiating costæ, or variously sculptured, sometimes smooth. Hinge more or less variable, usually with cardinal and lateral teeth; ligament external, short and prominent. Pallial line simple, or slightly sinuous.

Animal with mantle margins open in front; siphons very short, distinct, and furnished along the sides and bases with tentacular filaments; palpi slender and pointed. Gills two on each side, connected together behind. Foot very long, bent or geniculate.

The recent genera usually included in the family are *Cardium*, *Lævicardium* (or *Liocardium*), *Corculum*, and *Papyridea.* The species constituting the recent genus *Adacna* (including *Monodacna* and *Didacna*), sometimes placed in this family, seem to belong to a distinct group, on account of their elongated, plain, and united siphons, and their shorter compressed foot and deeply sinuous pallial line.

The Jurassic and Cretaceous group *Protocardia*, the Cretaceous *Liopistha*, the curious Eocene *Lithocardium*, and several unnamed extinct genera, also belong here. The remarkable palæozoic genus *Conocardium* is likewise often referred to this family, but its distinct coarsely prismatic cellular shell-structures has led some naturalists to think it may even belong to the very widely removed, anomalous order? *Rudista.* Although not prepared to adopt this conclusion, we are by no means clearly satisfied that it belongs properly to the *Cardiidæ.*

Genus PROTOCARDIA, Berych.

Synon.—*Cardium* (sp.), Sowerby, D'Orbigny, and others.

Protocardia, Beyrich, Zeitschr. f. Malak. 1845, 17.—Geinitz, Grundr. d. Verst. 1846, 421.—Conrad, Report Mex. Bound. Survey, 1858, 150.—Meek, Smithsonian Check List North American Cret. Fossils, 1864.

Etym.—πρωτος, first; Cardium.

Type.—*Cardium Hillanum*, Sowerby.

Shell globose-cordate, closed all around; subequilateral and but slightly oblique. Hinge with one or two cardinal teeth, and usually one anterior and one posterior lateral tooth, in each valve. Surface ornamented with very regular concentric costæ or striæ on the sides and front of the valves, and radiating costæ behind (the concentric markings sometimes very fine or obsolescent). Muscular impressions distinct; pallial line somewhat sinuous.

This group is nearly related to some of the sections of *Cardium*, but may be generally readily distinguished by its peculiar surface-sculpturing and slightly sinuous pallial line. Still, as its principal difference from forms referred by many to the genus *Cardium* consists in its surface-markings, most palæontologists regard it as forming only a subgenus under that group. Although we have no very serious objections to this conclusion, we think it more properly constitutes a distinct genus from *Cardium* as typified by *C. costatum*, Lin. Although it can nearly always be identified by its sculpturing alone, there are a few Cretaceous species in which these markings are very faintly defined, or probably in some case entirely obliterated. The radiating costæ or striæ on the posterior side of the valves, however, are nearly always present, even when the concentric sculpturing on the sides and front are obsolete. Very rarely, however, the radiating markings are obsolete; even in these cases, however, some traces of their existence can be seen in the crenulated margins of the posterior side of the valves.

This genus seems to be entirely confined to the Jurassic and Cretaceous rocks, unless a few recent shells, such as *Cardium pectenatum*, Lin. (not Lamk.), and *C. lyratum*, Sowerby, from the Philippines, may belong to the same group. These two species agree in form, and have very nearly the surface-markings of *Protocardia*, and unless they present some differences in the hinge or interior (we are not acquainted with the interior of these shells), they must be nearly related to the group under consideration. Still, they differ in having the sculpturing on the sides and front of the valves, somewhat oblique, and intersecting the anterior margins, instead of concentric and curving upwards in front. They were referred, by Swainson, Mörch, Chenu, Adams, and others, to *Liocardium*, but they differ materially from *C. lævigatum*, usually regarded as the type of the latter group.

Protocardia Shumardi.

Cardium Shumardi, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 182.
Cardium (Protocardium?) Shumardi, Meek & Hayden, ib. 418.

Protocardia Shumardi.

A. Side view of internal cast. *B.* Outline front view of same.

Shell small, oval subcordate, rather gibbous; anterior side rounded; base more broadly rounded; posterior side obliquely subtruncate above, and intersecting with an abrupt curve, the base below. Hinge margin rather short, and sloping slightly from the beaks, which are moderately elevated, gibbous, and nearly central; posterior umbonal slopes subangular. Surface of casts retaining only traces of small radiating costæ, or lines, on the prominent posterior umbonal slopes and the flattened postero-dorsal region. (Hinge and interior unknown.)

Length, 0.44 inch; height, 0.37 inch; thickness, 0.32 inch.

Our specimens of this species being casts, it is impossible to determine whether or not the surface was marked by regular concentric striæ on the middle and anterior portions, though it probably was. In its general appearance it bears some resemblance to *C. scitulum*, Meek (Trans. Albany Inst. 1856), a Cretaceous species from Vancouver's Island, but its truncated posterior margin is more oblique, and its posterior umbonal slopes more angular.

It seems to be more nearly related to the Oolitic species *C. semicostatum*, Lycett (An. Nat. Hist. 1850), but is longer in proportion to its height, and has less distinctly angular umbonal slopes. The specific name was given in honor of Dr. George G. Shumard, formerly of the Geological Survey of Texas.

Locality and position.—Southwest base of the Black Hills, in Jurassic beds, associated with *Eumicrotis curta*, *Belemites densus*, *Grammatodon inornatus*, &c. (No. 194.)

FAMILY ANATINIDÆ. (See page 36.)

Genus MYACITES (SCHLOT.), MUNSTER.

Synon.—*Myacites* (part.), SCHLOT. Petref. 1820, 176.—BRONN, Leth. 1837, 174.—MUNSTER, in GOLDF. Petref. Germ. II, 1840, 259.—WOODWARD, Man. Moll. 1850, 322.—MORRIS and LYCETT, Moll. Grt. Oolite, 1853, 111.

Panopæa (sp.), D'ORBIGNY, Palæont. Fr. III, 1844, 329, and of various others (not Menard de la Groye, 1809).

Pleuromya, AGASSIZ, Étud. Crit. IV, 1845, 231.—LEONH. and BRONN, Jahrb. 1846, p. 122.—CHENU, Man. Conch. II, 1862, 28.

Myopsis, AGASSIZ, Etud. Crit. IV, 1845, 251.—CHENU, Man. Conch. II, 1862, 28.

Etym.—μύαξ, a mussel.

Examp.—*Myacites musculoides*, SCHLOT.

Shell longitudinally ovate, oblong, or more or less elongate, very thin, nearly or quite equivalve, without a defined lunule; more or less gibbous in the central and umbonal regions. Extremities gaping, the posterior side more than the anterior, which is often nearly closed. Beaks moderately gibbous, placed between the middle and the anterior extremity. Hinge probably always with one more or less developed cardinal tooth in each valve; cardinal margin sometimes inflected, but more generally erect, excepting near the beaks; ligament external, short. Valves often with a broad, undefined depression extending from the beaks to the basal or antero-basal margin, usually deepening and widening as it descends. Surface with concentric striæ, and often more or less regular concentric ridges or costæ, the whole being, when well preserved, usually beset with minute granules. Muscular and pallial impressions very faintly marked; sinus of the latter broad and rounded.

Animal unknown

There is some confusion in regard to the limits of this genus, some authors including in it a wide range of forms evidently belonging to several genera, while others restrict it to a few of these, or reject the name entirely, placing the species in one or more of the allied groups. The name *Myacites* has perhaps met with less general acceptance because it was not proposed by Schlotheim, who first used it, as the name of a distinct genus, but to designate certain fossil shells supposed by him to belong to the existing genus *Mya*. He merely added the termination *ites* in this as in other instances, because the species he was figuring and describing were fossils, and not because he supposed them to belong to a new genus. By examining his work, it will be seen he wrote all the names of the genera to which he referred his fossil species in the same way; thus he ranged the fossil shells he supposed to belong to the genera *Pecten*, *Donax*, *Unio*, *Buccinum*, &c., under the names *Pectenites*, *Donacites*, *Unionites*, *Buccinites*, &c. Hence we cannot accept any of these as generic names established by him, when he may have by mistake included types of undescribed genera.

The first author, after Schlotheim, so far as our knowledge extends, who used the name *Myacites*, was Bronn (Leth. 1837); but as he used it in much the same sense that Schlotheim did—that is, as a provisional receptacle for fossil shells supposed to belong to the genus *Mya*, as he did *Turbinites*, &c.—we can scarcely regard him as having established it as a genus. In 1840, however, Munster adopted it regularly as the name of a distinct genus, and described under it *Myacites musculoides*, *M. ventricosus*, *M. elongatus*, *M. radiatus*, *M. mactroides*, Schlot.; *M. radiatus*, *M. grandis*, *M. obtusus*, Munster; and *M. Albertii*, Voltz; all of which appear to be congeneric with the first or typical species, with possibly one or two exceptions. We regard it as an established genus from that date, with *M. musculoides* as its type.

As already stated in the remarks respecting the affinities of the genus *Allorisma* (page 37), this group, as we understand it, seems to be very closely related to the Permian and Carboniferous shells upon which that genus was founded. For a statement of the principal points of difference between these two groups we would refer the reader to the remarks on page 37, in connection with the description of *Allorisma*.

These shells are also related to the genus *Pholadomya*, from which they differ in never having radiating costæ, as well as in their granulated surface. They also seem to be entirely destitute of pearly internal layer seen in the shells of that genus. From *Panopæa*, to which they are often referred, they differ in being much thinner shells, as well as in their granulated surface and much more faintly marked muscular and pallial impressions. Indeed, they appear, from all analogy, to belong even to the very distinct family *Anatinidæ*, instead of the *Saxicavidæ*.

The genus *Myacites* probably first appeared during the Triassic epoch, though we are not sure that some of the species usually referred to *Allorisma* from the older rocks are really generically distinct. It seems to have reached its maximum development during the deposition of the Jurassic rocks, and continued to exist until after the commencement of the Cretaceous epoch, during the earlier part of which it probably became extinct.

Myacites nebrascensis.

(Plate IV, Fig. 5.)

Myacites Nebrascensis, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 182; ib. Oct. 1860, 418.

Shell elongate-subelliptical, rather convex; extremities narrowly rounded, the posterior end being sometimes apparently obliquely subtruncate, and more or less gaping above. Base nearly straight, or very slightly sinuous, along the middle; rounding up gradually toward the ends. Dorsum behind the beaks, concave in outline; posterior umbonal slopes gibbous, or prominently rounded; antero-ventral region a little compressed, or contracted, from near the middle of the base, obliquely forward and upward. Beaks moderately elevated, gibbous, incurved, and located near the anterior end. Surface ornamented by concentric striæ, and small, very obscure, irregular parallel wrinkles.

Length, about 1.43 inch; height, 0.69 inch; breadth, 0.59.

Our specimen being a cast, has probably lost some of its finer surface characters, though it evidently never had radiating costæ, like we see on well-marked species of *Pholadomya*, as defined by most authors. Its true generic relations, however, must remain doubtful until better specimens can be obtained.

Locality and position.—Southwest base of the Black Hills, near the lower part of the Jurassic series of that region.

Myacites subellipticus.

(Plate IV, Fig. 6, *a*, *b*, *c*.)

Panopæa (*Myacites*) *subelliptica*, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. March, 1858, 52; ib. Oct. 1860, 418.

Shell narrow, elliptical, or subovate, moderately convex; extremities rather narrowly rounded, the posterior end being more compressed than the other; base forming a very broad semi-elliptic curve; beaks located in advance of the middle, rather depressed, the right one sometimes a little more elevated than the other; surface of cast marked by small irregular wrinkles of growth; hinge and muscular and pallial impressions unknown.

Length, 2.08 inches; height, 1.09 inch; breadth, 0.70 inch.

In its general appearance this species resembles *Panopæa peregrina*, D'Orbigny, as figured by Murchison, de Verneuil and Keyserling, in their Geol. Russ. II, part 3, pl. xl, fig. 10, but it is proportionally a little shorter, narrower posteriorly, and more convex in the antero-ventral region, while its extremities appear to be less gaping.

It is even more nearly similar in form to *P. Neocomiensis*, Lehm. sp., from the Lower Green Sand of the Old World, but differs from most of the figures we have seen of that species, in being more narrowly rounded at the extremities, and in having less prominent beaks.

Locality and position.—Southwest base of the Black Hills, near the lower part of the Jurassic series of that region. (Type No. 200.)

Genus THRACIA, Leach.

Synon.—*Thracia*, Leach, MSS. 1819; Blainville, Dict. Sci. Nat. XXXII, 1824, 347; and Malac. 1825, 564.—Rang, Man. 1829, 324.—Deshayes, Encyc. Meth. III, 1830, tab. 1832; ib. p. 1038; and in Lamk. 2d ed. VI, 1835, 82.—Menke, Syn. 2d ed. 1830, 119, &c. Not *Thracia*, Westwood, 1840 (gen. Insects).
Odoncinetus, Da Costa, Cat. Syst. 1829, 32.
Odontocineta (Corr.), Agassiz, Index Universalis, 1846, 255.

Etym.—Θράκιος, Thracian?

Type.—*Mya pubescens*, Penn.

Shell longitudinally oblong or ovate, inequivalve, rather thin; posterior side more or less contracted, compressed, and gaping; surface concentrically striate, sometimes minutely scabrous. Hinge consisting of a thick, slightly prominent cartilage process in each valve, with a free crescentic ossicle in front. Ligament partly internal. Pallial sinus rather shallow; muscular impressions small. Outer shell layer consisting of distinct nucleated cells.

The genus *Thracia* was probably introduced during the deposition of the Liassic or oldest Jurassic rocks. It also ranges through the later formations, and appears to attain its greatest development in our existing seas. The species, however, were quite numerous at several intermediate periods, particularly during the deposition of the Neocomian rocks.

We observe several authors place *Rupicola*, of Bellevue, 1802, as a subgenus under *Thracia*, while others adopt it as a distinct genus. Whether we regard the type upon which it was founded as generically or subgenerically distinct, however, Bellevue's name should probably not be retained, since it was used by Brisson, in 1760, for a genus of birds, now adopted by ornithologists.

Thracia? sublævis.

(Plate IV, Fig. 4, and 4*a*.)

Thracia? sublævis, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 182; ib. Oct. 1860, 418.

Shell elongate, or narrow oblong-oval, rather compressed. Anterior end narrowly rounded; base nearly straight along the middle, rounding up toward the ends; posterior side longer than the other, rounded, or slightly truncate, and apparently gaping a little at the extremity; dorsal border straight or concave in outline, and nearly horizontal behind the beaks, declining more abruptly in front. Beaks moderately elevated, the right one being usually a little higher than the other; located in advance of the middle; posterior umbonal slopes prominently rounded. Surface concentrically striate.

Length, 1.19 inch; height, 0.63 inch; breadth, about 0.32 inch.

Not having seen the hinge or the interior of this shell, we are left in doubt respecting its true relations, and merely place it provisionally in the above genus. Our specimens are all casts, but some of them retain traces of concentric lines, which appear to be the only kind of surface markings it had. Behind the beaks there is a narrow area or escutcheon, apparently formed by the thickening or inflection of the cardinal margin; this, however, may exist only on the internal cast.

Locality and position.—Near middle of the Jurassic beds, at the southwest base of the Black Hills. (Type No. 197.)

Thracia? arcuata.

(Plate IV, Fig. 8.)

Thracia? arcuata, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. May, 1860, 182; ib. Oct. 1860, 418.

Shell small, longitudinally subovate, more or less arcuate, moderately convex. Extremities rather narrowly rounded, and gaping a little. Cardinal margin sloping from the beaks; anterior slope more abrupt than the other. Beaks rather elevated, and unequal, that of the right valve being higher than the other, located in advance of the middle; posterior and anterior umbonal slopes prominent. Sides of the valves compressed or slightly concave in the central region, near the base. Surface of cast retaining small concentric marks of growth. (Hinge and interior unknown.)

Length, 0.62 inch; height, 0.34 inch; thickness, 0.23 inch.

This shell is more nearly related to the last than to any of the other species yet known from the rocks of the upper Missouri country, but differs in being more gibbous, and in having the valves more compressed or concave near the middle of the base, which imparts an arcuate outline to the ventral border. Its dorsal margin is also much less nearly horizontal, in consequence of the greater elevation of its beaks. Like the last, it has along the cardinal border of the internal cast, behind the beaks, a narrow circumscribed area or escutcheon, bounded by an obscure angle along each side. Knowing nothing of the nature of its hinge, or pallial line, we cannot determine its generic relations with much confidence.

Locality and position.—Same as last. (No. 211.)

Genus PHOLADOMYA, Sowerby.

Synon.—*Pholadomya*, G. B. Sowerby, Genera Shells, 1823, fasc. 19.—Latr. Fam. Nat. 1825.—Defrance, Dict. Sci. Nat. t. XXXIX, 1826, 535.—J. Sowerby, Min. Conch. 1827, tab. 545.—Deshayes, Encyc. Meth. III, 1830,

tab. 1832; ib. 756; again in LAMK. 2d ed. VI, 63.—F. A. ROEMER, Verst. Ool. 1836, 126.—BRONN, Leth. 1837, 384.—AGASSIZ, Etud. Crit. Mol. Foss. 2d liv. 1842, 37.—HANLEY, Ill. Cat. 1844, I, 18, &c. &c.
Pholadomyœa, FLEMING, Hist. Brit. An. 1828, 408 and 424.
? *Cymella*, MEEK, Smithsonian Chk. List Cret. Foss. 1864, 34.
Etym.—Pholas; Mya.
Type.—P. candida, SOWERBY.

Shell thin, equivalve, pearly within; longitudinally oblong, oval, or subtrigonal; inequilateral and ventricose; extremities usually both gaping, but the posterior more widely than the other. Surface ornamented with radiating costæ, crossed by concentric striæ, or more or less distinct, sometimes nodular, ribs. Hinge with an obscure lamellar tooth, and a small triangular pit in each valve. Ligament short, external. Pallial line and muscular impressions generally faintly marked; the latter broadly sinuate.

The animal of *Pholadomya candida*, according to Owen, has its mantle provided with four openings—a pedal, a siphonal, and an anal aperture, with a fourth small circular orifice at the under part of the siphons. The gills are thick and finely plaited, the outer lamina being extended dorsally. The foot is provided with a small accessory bifurcating appendage behind.

Prof. Agassiz, who has produced the most important work on this genus, separates the species into two principal sections, and again divides each of these into several subordinate groups, as follows:—

SECTION I.—*Species Without a Circumscribed Cardinal Area.*

1. "Multicostatæ," AGASSIZ.
Shell more or less elongated; radiating costæ numerous, well defined.
Examples.—P. semicostata and *P. multicostata*, AG. (*Jurassic and Cretaceous.*)

2. "Trigonatæ," AGASSIZ.
Shell subtrigonal or more or less oblong; anterior side gibbous, often closed; posterior more compressed and distinctly gaping; beaks generally elevated, sometimes perforate. Surface with distinct concentric ridges, often extending upon the extremities of the valves, and crossed upon the flanks by well-defined tubercular radiating costæ; cardinal area distinct, but not sharply defined.
Examples.—P. arcuata and *P. nuda*, AG. (*Cretaceous, Tertiary, and Recent.*)

3. "Bucardinæ," AGASSIZ.
Shell subtrigonal, or more or less ovoid, gibbous, and comparatively thick; truncated, somewhat gaping, and usually flattened anteriorly; posterior side distinctly gaping; beaks gibbous and closely contiguous. Surface with strong, often tubercular radiating costæ on the flanks; muscular and pallial impressions distinct.
Examples.—P. cincta and *P. decussata*, AGASSIZ. (*Lias to Tertiary.*)

SECTION II.—*Species With a Circumscribed Cardinal Area.*

4. "Flabellatæ," AGASSIZ.
Shell usually much elongated; radiating costæ prominent and often distant, generally confined to the flanks. General aspect similar to the "*Multicostatæ*," but differing in the possession of a defined cardinal area.
Examples.—P. pelagica and *P. similis*, AGASSIZ. (*Jurassic.*)

5. "Ovales," AGASSIZ.
Shell ovoid, more or less compressed; one or the other of the extremities gaping: cardinal area sometimes not very distinct behind; costæ linear, often crenate.
Examples.—P. tenuicostata and *P. pectinata*, AGASSIZ. (*Jurassic.*)

6. "Cardissoides," AGASSIZ.
Shell subtrigonal, similar to the "*Bucardinæ*" of the first principal division, but differing in the possession of a defined cardinal area, and in having the costæ less numerous and more faintly marked.
Examples.—P. cancellata and *P. cardissoides*, AGASSIZ. (*Jurassic.*)

If we disregard the distinctions based upon the presence or absence of a circumscribed cardinal area (and there appear to be various intermediate gradations in this character), the foregoing six groups may probably be reduced to four, by uniting the "*Flabellatæ*" with the "*Multicostatæ*," and the "*Cardissoides*" with the "*Bucardinæ.*" As thus arranged, these groups would apparently correspond nearly with what are usually regarded as subgenera, in conchology.

There is, however, another little group, differing, it is believed, from all of those defined by Prof. Agassiz, though probably nearest the "*Ovales.*" It is only known in the Cretaceous rocks, and was called *Cymella* by the writer, in the Smithsonian Check List of North American Cretaceous Fossils, 1864, p. 34. The type is *Pholadomya undata*, Meek and Hayden, a small oval, subequilateral, rather compressed shell, with very regular concentric undulations (like those of *Inoceramus*), crossed by impressed radiating lines, only visible near the middle of the valves; cardinal area distinct.

Mr. Conrad has also proposed two subgenera under *Pholadomya*, viz., *Anatimya* and *Margaritaria*. The type of the first is his *Pholadomya anteradiata*, a Cretaceous species; and the other was found upon his *P. abrupta*, from the Miocene. We are not acquainted with these shells, but from the figures and descriptions, incline to the opinion that they should be regarded as the types of distinct genera, particularly the latter.

The genus *Pholadomya* was probably first introduced during the Liassic period, and attained its greatest development during the deposition of the later members of the Jurassic system. It was also well represented in the Cretaceous, and some two or three species have been described from the Tertiary rocks. A single species only (the type of the genus) is known to inhabit our existing seas. It is found on the shores of the island of Tortola, West Indies.

Some apparently closely allied forms are found in the Triassic, Permian, and Carboniferous rocks, but they all want the radiating costæ of the true Pholadomyas, and are referred to *Allorisma*, *Myacites*, *Platymya*, *Chænomya*, &c.

Pholadomya humilis.

(PLATE IV, Fig. 3, *a*, *b*.)

Pholadomya humilis, MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. May, 1860, 182; ib. Oct. 1860, 418.

Shell longitudinally oblong, ventricose. Posterior end rounded, and more or less gaping; base nearly straight along the middle; anterior end very short, narrowly rounded below the beaks. Dorsum nearly parallel with the base, slightly concave in outline; escutcheon lanceolate, and bounded by an obscure angle on each side. Beaks depressed, gibbous, incurved, and located in advance of the middle. Surface ornamented by small, regular, concentric wrinkles, crossed by a few raised lines, or small, distant costæ, which radiate from the back part of the beaks to the posterior and postero-basal margins.

Length, about 1.06 inch; height, 0.47 inch; breadth, 0.52 inch.

As far as can be determined from our imperfect specimens, this species seems to be new. It bears some resemblance in form to *P. subelongata*, Meek (Trans. Albany Institute, vol. IV, p. 42), from rocks of Cretaceous age on Vancouver's Island, but its beaks are more depressed, and its radiating costæ more distant, as well as more obscure.

Locality and position.—Lower part of the Jurassic beds at southwest base of Black Hills. (Type No. 217.)

Class GASTEROPODA.

Subclass PULMONIFERA.

Order Inoperculata.

Suborder LIMNOPHILA.

Family LIMNÆIDÆ.

Shell dextral or sinistral, thin, and horn-colored, varying from elongate-subcylindrical to ovate or discoidal; capable of receiving the entire animal when retracted; aperture simple; columella with or without a fold; lip sharp.

Animal with a short dilated muzzle; tentacles short and compressed, or elongate and slender, bearing the sessile eyes at their inner bases. Mantle with its margin simple or very rarely digitate. Mouth armed with a corneous upper mandible; lingual teeth numerous, arranged in transverse rows, the central minute and the lateral uncinate. Respiratory orifice on the right side, and the vent at the left of the neck. Foot ovate or lanceolate.

The above diagnosis is framed so as to include three subordinate groups, presenting in their various species a wide range of forms, and more or less important differences in the characters of the animal. These sections or subfamilies may be characterized as follows:—

1. Limnæinæ.

Shell spiral, dextral. Animal with tentacles short and flattened, or triangular.

Includes *Limnœa*, and probably *Chilina* and *Amphipeplea.*

2. Physinæ.

Shell sinistral, otherwise much as in the *Limnœinœ.* Animal with tentacles elongate and slender.

Includes *Physa*, *Physopsis*, *Aplexa*, *Macrophysa*,[1] and *Camptoceras.*

3. Planorbinæ.

Shell involute, discoidal, dextral, or sinistral[2]? aperture more or less crescentic. Animal with tentacles as in the *Physinœ.*

Includes *Planorbis Taphius*, *Bathyomphalus*, *Gyraulus*, and *Segmentina.*

Notwithstanding the striking differences of form observed in the shells here ranged under the sections of this family, the animals of these several types agree in so many respects, that conchologists generally place them together in one family; while some also include *Ancylus*, *Acroloxus*, *Latia*, and *Gundlachia*.

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[1] *Macrophysa*, Meek. The type for which this name is proposed is the curious Eocene species described by Deshayes (Coq. Foss. II, 90; X, 11 and 12) under the name *Physa columnaris.* It is a remarkably elongated, subcylindrical shell, with a deep suture, and a comparatively very small body whorl. Its aperture is oval and small, or less than one-third the entire length of the shell, angular behind, and subangular or abruptly rounded in front; columella smooth, flattened, and somewhat twisted. It seems to be intermediate between *Camptoceras* and *Aplexa*, and may possibly be ranged as a subgenus under the latter.

[2] See note, p. 106.

In their habits, these mollusks all agree in being inhabitants of fresh water. They are true air-breathers, being compelled to come to the surface occasionally for that purpose. They are widely distributed in almost all parts of the world where ponds, streams, and other bodies of fresh water exist, and feed upon confervæ and other aquatic vegetation.

Subfamily PLANORBINÆ (p. 104).

Genus PLANORBIS, Müller.

Synon.—*Planorbis* (part), Müller, Verm. Terest. et Fluv. 1774, 152; Zool. Dan. 1776, 238.—Brug. Encyc. 1789, I, xvi.—Cuvier, Tab. Elem. 1798 (not *Planorbis*, Lamarck, Prodr. 1799, 76; nor 1801, Syst. An. 93).
Orbis, Schrot. Jour. F. d. L. d. III, 1776, 10 (not Lea, 1833).
Vortex, Humphrey, Mus. Col. 1797 (58, sec. ed.).
Anisus, Fitz. Verz. 1833, 111.
? *Bathyomphalus*, Agassiz, Catal. 1837, 20.
Helisoma, Swainson, Malac. 1840, 337.
Spirorbis, Swainson, ib. (not Lamarck, 1815).
Planorbina, Haldeman, Fresh-water Univ. U. S. 1842, 14.
Planorbella, Haldeman, ib. 1842.
? *Gyraulus*, Agassiz, Nouv. Mém. Soc. Helv. I, 1837.
Planodiscus, Stein, * * * 1843.
? *Taphius*, H. & A. Adams, Genera Recent Mol. II, 1856, 264.
Menetus, H. & A. Adams, ib.
Etym.—*Planus*, flat; *orbis*, an orb.
Type.—*Helix cornea*, Linnæus.

Shell dextral, or sinistral?[1] discoidal or subdiscoidal, the whorls being nearly or quite on the same plane; right side generally flat, or sometimes either a little elevated or concave; left side more or less excavated; volutions rounded, compressed, or angular; aperture crescentic or suboval, sometimes dilated; peristome thin, incomplete, right margin projecting.

The typical forms of this genus have the shell much depressed, and the volutions numerous, rounded or without angles, and visible on both sides; while the mouth is not dilated. As above defined, however, it is made also to include several subordinate groups which depart more or less from the typical species, though generally placed here by conchologists. Some of these types should probably stand as distinct genera, but as it is scarcely practicable, in Palæontology at least, always to distinguish between them, we have preferred to define the genus in its widest sense. The subordinate groups, however, not agreeing exactly with the typical forms, may be characterized as follows:—

1. Planorbella, Haldeman.

Shell with few whorls, which are usually angular on the left side; aperture distinctly expanded, or bell-shaped.

Type.—*Planorbis campanulatus*, Say.

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[1] Conchologists generally regard these depressed shells as being dextral; but O. A. L. Mörch offers some apparently good reasons for viewing them as properly sinistral forms (Conch. Jour. xi., 2d Ser. 235). This conclusion seems to be sustained by the form of the young of some American species, one of which was described by DeKay as a truncated *Physa*. On the other hand, however, monstrosities of some foreign species with an elevated spire, are generally dextral.

2. Helisoma, SWAINSON.

Shell ventricose, concave on both sides; volutions few, generally angular on one or both sides, broadly rounded on the periphery.

Type.—P. bicarinatus, SAY.

3. Taphius, H. & A. ADAMS.

Shell ventricose, somewhat irregular; whorls rounded on the outer side, prominent or subangular around the rather small, deeply excavated umbilical cavity of the left side. Aperture large, obovate, straight within.

Type.—P. andecolus, D'ORBIGNY.

4. Menetus, H. & A. ADAMS.

Shell depressed, volutions increasing rapidly in size; aperture suboval; periphery more or less angular.

Example—P. angulatus, PHIL.

5. Anisus, FITZINGER.

Shell strongly depressed; volutions very numerous; periphery angular.

Example.—P. carinatus, MÜLLER.

6. Bathyomphalus, AGASSIZ. (=*Spirorbis*, SWAINSON, not LAMK.)

Shell discoid, rounded on the periphery; whorls numerous, closely embracing on the left side, exposed on the right; aperture narrow, crescentic; umbilical cavity on the left side narrow and profound.

Type.—Helix contorta, LINNÆUS.

7. Gyraulus, AGASSIZ. (=*Nautilina*, STEIN.)

Shell discoid, slightly convex on the right side, flat or broadly concave on the left; volutions few, rapidly increasing in size, obliquely depressed, but not angular.

Example.—P. albus, MÜLLER.

So far as at present known, the genus *Planorbis* seems to have been first introduced during the Liassic epoch; it is also known to have been represented during the deposition of the Wealden formation. Many species have likewise been found in the fresh-water Tertiary deposits of various countries, though the genus seems to attain its greatest development at the present time, and is widely distributed, particularly in northern temperate regions.

Planorbis veternus.

a-c ?

(PLATE IV, Fig. 1 and 1*a*, *b*.)

Planorbis veternus, MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. Oct. 1860, 418.

Shell small, planorbicular; right side distinctly concave. Volutions three and a half to four, more or less rounded, increasing rather rapidly in size; slightly concave on the inner side for the reception of each succeeding whorl, and prominent or subangular a little within the middle on the upper side; most convex outside of the middle below. Concavity of left side rather large, basin-shaped, and, like that on the right, showing all the whorls. Aperture oblique, a little oval. Surface nearly or quite smooth.

Greatest diameter, 0.15 inch; do. of outer whorl, 0.05 inch.

Locality and position.—Southwest base of the Black Hills, associated with *Unio nucalis*, *Viviparus Gilli*, and *Valvata? scabrida;* also, apparently, with *Ammonites Henryi*. As these fresh-water shells were found in loose fragments, we are not sure they hold the same position as the Ammonite, though they were picked up at the base of an outcrop of hard bluish-gray limestone, in masses agreeing in their lithological characters with the bed containing the Ammonite. They may possibly be Tertiary species, but differ from all those we have seen from rocks of that age in the Northwest. It is only provisionally we place them along with the Jurassic forms. (Type No. 317.)

SUBCLASS PROSOBRANCHIATA.

ORDER **Riphidoglossata.**

SUBORDER PODOPTHALMA.

FAMILY NERITIDÆ.

Shell generally thick, varying from subovate or ovate-subglobose, to depressed hemispherical, not umbilicate; spire very small or sometimes nearly obsolete, often lateral, simple within, from the absorption of the inner whorls; body volution very large; aperture semilunar, not pearly within.

Operculum wholly, or in part shelly, subspiral, articulated with the inner lip by one or two processes.

Animal without lobes or neck lapets; muzzle broad, short, and more or less emarginate; tentacles long, subulate, and having the eyes on peduncles at their outer posterior bases. Foot oblong-subtrigonal; margins simple, not provided with filaments or membrane. Dentition much as in the *Trochidæ* (×.3, 1, 3.×), the rachidian tooth being very small, laterals unequal, and the uncini numerous, with the first one large, and the others very small, slender, and hooked.

This family embraces a large number of species, which have been variously grouped into genera and subgenera by different authors. The groups most usually adopted for the reception of the recent species are *Nerita*, *Neritella*, *Clithon*, *Alina*, *Neripteron*, and *Catillus*. The extinct genera known at this time are *Neridomus*, *Velates*, *Deshayesia*, *Neritoma*, and *Pileolus*. There are, however, probably several undescribed genera amongst the fossil species referred to *Nerita;* and some of the Carboniferous shells referred to McCoy's genus *Naticopsis* (though not the typical species) seem to belong to some genus of this family rather than to the *Naticidæ*.

Genus NERITELLA, HUMPHREY.

Synon.—*Neritella*, HUMPHREY, Mus. Col. 1797, 57.—GRAY, Zool. Proc. 1847, 148.—H. & A. ADAMS, Genera Recent Mol. I, 1854, 380.
Neritina, LAMK. Phil. Zool. 1809; Hist. VI, 1822, 182.—BRONN, Leth. 1837, 390.—PUSCH, Pol. Palæont. 1837, 97.—SWAINSON, Malacol. 1840, 347.—RECLUZ, Revue Zool. 1841, 273, &c.
Theodoxus, MONTFORT, Conch. Syst. II, 1810, 351.
Lamprostoma, RAFINESQUE, Anal. Nat. 1815 (not SWAINSON, 1840)
Nereina, DE CRIST. and JAN. Cat. 1832.
Clypeolum, RECLUZ, Revue Zool. 1842, 234.
Puperita, GRAY, Guide to the Syst. Dist. Mol. 1857, 137.
Etym.—*Nerita* dimin.
Type.—*Nerita viridis*, LIN.

Shell ovate, or rhombic subglobose, rather thin, covered with a corneous epidermis; surface smooth or striate, and often ornamented with beautiful and vivid colors. Spire short, more or less conoid. Aperture semilunar; inner lip and columella straight and flattened or septiform, with a smooth or crenulated margin.

Operculum thin, testaceous, with a corneous margin; outer surface smooth; provided with two apophyses; the upper shorter, sometimes dilated and crested, the lateral arcuate.

The Neritellas mainly inhabit fresh water, but they are often found in brackish, and sometimes even in salt-water. Others are amphibious, and crawl out upon the roots and trunks of trees along the margins of streams, ponds, and other bodies of water. The genus embraces a considerable number of species which are widely distributed, almost exclusively in tropical and torrid regions.

Conchologists differ in regard to the limits of this group, some including in it, as sections or subgenera, *Dostia*, *Alina*, *Neripteron*, and *Clithon;* while others regard not only these, but some of the others we have here included in the list of synonyms, as so many distinct genera.

The typical Neritellas differ from the closely allied groups *Dostia*, *Alina*, and *Neripteron*, in being more symmetrical, less depressed shells, with a more developed and less eccentric spire, as well as a greatly less expanded aperture, and a less developed lip.

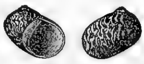
From *Clithon*, with which they agree more nearly in form, they differ in never being spinous, and always without a tooth near the upper part of the columella. From the genus *Nerita* these shells may be distinguished by their much thinner and smoother shells, and smooth or less strongly dentate columella, as well as by the exclusively marine habits of the former.

It is difficult to arrive at a satisfactory conclusion in regard to the geological range of this genus until the affinities of a number of fossil species have been more accurately determined. It seems, however, to be an older type than *Nerita;* indeed, as already intimated, even some Carboniferous forms usually placed in the genus *Naticopsis*, are very closely similar to *Neritella*, though doubtless generically distinct. Some of the so-called Neritas from European Jurassic beds probably belong to this genus, though most of them present differences that place them either in the genus *Neridomus*, or apparently in allied, but undefined genera. If we are right in referring the bed from which the following described species was obtained, to the horizon of the Jura, it would establish the existence of the genus during that epoch beyond doubt, since it is a typical *Neritella*.

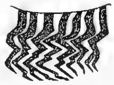
A few of the Cretaceous Neritas, so-called, seem also to belong here, and the genus was well represented during the tertiary epoch. It attains its maximum development, however, at the present time.

Neritella Nebrascensis.

Neritella Nebrascensis, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1861, 444.



Neritella Nebrascensis.



Neritella Nebrascensis.
Enlargement of bands of color.

Shell small, obliquely rhombic-oval; volutions three to three and a half, convex, increasing rapidly in size, the last one composing more than nine-tenths of the entire shell; suture well defined. Aperture broad ovate. Columella moderately thickened and flattened, its margin a little arched and smooth; usually having a slight umbilical groove along the anterior outer margin of the inner lip. Surface smooth, or only having obscure lines of growth; ornamented with alternate dark and light-colored zigzag bands crossing the whorls at right angles to the suture.

Height, 0.40 inch; greatest transverse diameter, measuring from the outer side of the aperture obliquely upwards to the most prominent part of the body whorl on the opposite side, 0.44 inch; height of the aperture, 0.35 inch; breadth of do., 0.25 inch.

This must have been a very pretty little shell before its bands of color were partly obliterated by the fossilizing process. A few of the specimens, however, still retain these colored markings so as to be quite distinctly seen when moistened. We know of no fossil species with which it is liable to be confounded. Amongst recent species, it is perhaps most nearly represented by the European *N. rivalis*, Parreyss, which is of about the same size, and has much the same form and style of coloring, though its aperture is rather less expanded, and its inner lip a little wider; while its bands of color are narrower, and not so abruptly nor so frequently deflected.

This species belongs to the subordinate group *Neritina*, as defined by H. & A. Adams, and Chenu.

Locality and position.—Head of Wind River, Dakota Territory, where it occurs associated with *Lioplacodes veternus*, M. & H., in beds supposed to be of Jurassic age. (Type No. 1979.)

ORDER **Cyclobranchiata.**

? FAMILY DENTALIIDÆ.

Shell tubular, slightly arched, truncated and open at both ends; aperture at the smaller end sometimes with a slit or fissure on the dorsal side.

Operculum wanting.

Animal with lingual membrane comparatively broad; teeth in three series, the middle denticulate, and the laterals broad and simple. Head rudimentary, being without eyes or tentacles; mouth with cirrhated lips. Mantle circular, thick and fleshy in front, and covering the forepart of the body. Gills two, symmetrical, and placed behind the heart. Foot conical, small, or rudimentary, with two symmetrical side-lobes, and an attenuated hollow base connecting with the stomach, which is provided with a strong internal "gizzard."

Although these curious mollusks are known to possess red blood like the earthworms, the rudimentary condition of their eyeless head, without traces of tentacles, the position of their symmetrical gills, and the union of the sexes in each individual, are characters showing their low rank amongst the *Gasteropoda*. They are generally placed with the *Prosobranchiata*, though, as has been suggested by several conchologists, they might with almost equal propriety be ranged with the *Opisthobranchiata*.

This family includes only the genera *Dentalium*, *Entalis*, and *Helonyx*.

Genus DENTALIUM, Lin.

Synon.—*Tubulus, Dentale, Dentalites, Syringites*, &c., of ante-Linnæan authors.
Dentalium, Linnæus, Syst. Nat. 1740, sec. ed. 64; ib. sixth ed. 1748, 75; ib. tenth ed. 1758, 785; ib. twelfth ed. 1768, 1263.—Lamk. Prodr. 1799, 78; Syst. An. 1801, 326; Hist. Nat. V, 1818, 341.—Schum. Ess. 1817, 263.—Blainv. and Defr. Dict. Sci. Nat. XIII, 1819, 69, &c.
Etym.—*Dens*, a tooth.
Examp.—*Dentalium elephantinum*, Lin.

Shell elongate, terete or angular, smooth, costate or striate; aperture circular; lip simple, entire; margin of the posterior opening without a fissure.

The shells of this genus are very similar to those of the allied group *Entalis*, but the latter differ in having a slit or fissure in the dorsal side at the smaller extremity. The genus *Ditrupa*, one of the marine worms, also secretes a shelly tube, sometimes resembling that of *Dentalium*, though it can generally be distinguished from the latter by having its sides more or less ventricose near the aperture, while the shell of *Dentalium* is gradually and regularly tapering from the larger to the smaller extremity.

The genus *Dentalium* seems to have made its first appearance during the Devonian epoch. It is also known to occur in the Carboniferous rocks, and ranges through all the succeeding formations. It is well represented in the existing seas, and probably attains its maximum development at the present time. The recent species are usually found in deep seas, where they are said to feed upon *Foraminifera* and small bivalves.

Dentalium subquadratum.

Dentalium? subquadratum, Meek, Proceed. Acad. Nat. Sci. July, 1860, 311.

Shell small, thin, regularly and slightly arcuate, very gradually tapering, flattened on four sides so as to present a subquadrangular section, the angles being a little rounded; section of internal cavity circular; surface apparently without longitudinal or transverse striæ.

Length, about 1 inch; diameter of larger end, 0.05 inch; do. of smaller end, 0.02 inch.

This species is remarkable for its quadrangular form, which gives rise to some doubts whether or not it is a true *Dentalium;* though we know of no other genus to which it can be referred.

Locality and position.—North Platte River, at the Red Buttes, Lat. 42° 50′ north, Long. 106° 40′ west. (Type, No. 677.)

Dentalium subquadratum.

Order **Ctenobranchiata** (= *Pectinibranchiata*).

Suborder ROSTRIFERA.

Family VALVATIDÆ.

Shell small, turbinate or discoidal, provided with an epidermis; aperture with an entire peritreme; last volution sometimes free at the aperture. Operculum corneous, circular, multispiral, the whorls being provided with a thin elevated margin.

Animal with muzzle produced; tentacles cylindrical; eyes at their outer bases. Mantle simple in front; branchial plume pectinated, partially exposed on the right side when the animal walks; the laminæ pinnate, spirally twisted, protected by a respiratory lobe. Foot bifid anteriorly. Lingual teeth (3. 1. 3) hooked and denticulate, the central series broad, lateral lanceolate.

This family embraces but the typical genus *Valvata*, and *Lyogyrus*. The species are rather widely distributed in temperate regions, and inhabit lakes, ponds, ditches, and sluggish streams. They are the only known Prosobranchiate Gasteropods having exposed gills.

Genus VALVATA, Müller.

Synon.—*Valvata*, Müller, Hist. Verm. II, 1774, 198; and Zool. Dan. Prodr. 1776, 239; Studer, Coxe Trav. III, 391; Abildgaard, Skrivt. af Naturh.—Selsk. 1794, III, 61; Drapärn. Tabl. 1801, 30; and Hist. 1805, 26, 28, 41; Lamk. Extr. d'un Cours. 1812, and Hist. VI, 1822, II, 171.
Valvearius, Dum. Zool. Anal. 1806, 164.
Gyrorbis, Fitzinger, Verz. 1833, 117.
Planella, Schlüt, Vz. 1838, 13.
Valvata, Berge, Conch. Buch, 1847, 17, 20, 26.
Tropidina, H. & A. Adams, Genera Recent Mol. 1856, 344.
Etym.—*Valvatus*, having folds or valves.
Type.—*Valvata cristata*, Müller.

Shell umbilicate; spire usually much depressed, sometimes moderately prominent; whorls rounded or carinate; epidermis corneous; aperture circular; lip thin and sharp.

The shells of this genus are distinguished from those of the allied type *Lyogyrus* by never having the last turn free at the aperture. The group embraces two rather marked sections, as follows:—

1. **Valvata** (proper) = *Gyrorbis*, Fitzinger, = *Planella*, Schlut.
   Shell greatly depressed or planorbicular; with a very wide umbilicus and rounded whorls.
   Example.—*V. cristata*, Müller.
2. **Tropidina,** H. & A. Adams.
   Shell turbinate, or having the spire more or less prominent, and the volutions either carinate or rounded.
   Examples.—*V. tricarinata*, Say, and *V. piscinalis*, Müller.

As there are some slight differences in the details of the lingual teeth in these two groups, as well as in the form of the shell, it is possible they may more properly constitute distinct genera.

The Messrs. H. & A. Adams admit three subgenera under this genus, in their valuable work on the genera of Recent Mollusca. Regarding such forms as *V. piscinalis* as typical, they adopt Fitzinger's name *Gyrorbis*, for such types as *V. cristata*, Müller, and propose the name *Tropidina* for forms like *V. tricarinata*, Say. As the genus *Valvata*, however, was originally founded by Müller, upon *V. cristata*, that species must be regarded as the type, and as *Gyrorbis* was also founded upon the same shell it must be viewed as exactly synonymous with *Valvata* proper, and cannot be used for another group. Although *Tropidina* was proposed for the reception of carinated forms only, there is no reason why it should not also include the other turbinate species, with rounded whorls, and a more or less prominent spire, since the carinated character is not constant even in the species *tricarinata*.

If the following described species really belongs to this genus, it would seem to establish the existence of the group during the deposition of the middle or older members of the Jurassic system. This conclusion, however, should not be adopted until all doubts are removed in regard to its generic characters, and exact stratigraphical position. The existence of this genus during the Wealden period is, however, well established. It is also well represented in the fresh-water Tertiary deposits of Europe and occurs in the Tertiary beds of the central districts of North America, and probably attains its greatest development at the present time.

Subgenus TROPIDINA, H. & A. Adams (p. 112).

Valvata? scabrida.

(Plate IV, Fig. 2, *a*, *b*.)

Valvata? scabrida, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Oct. 1860, 418.

Shell small, subglobose, thin; spire rather depressed. Volutions three to three and a half, increasing rapidly in size, very convex; subangular around the upper outer side, and horizontally flattened between the angle and the suture; ventricose on the outer and under sides. Suture well defined; aperture round, oval? Surface ornamented by strong, regular marks of growth.

Length and breadth, each about 0.16 inch.

Not having seen specimens of this little shell sufficiently detached from the very hard, brittle, argillo-calcareous matrix, to show very satisfactorily the form of its aperture, we are left in some doubt respecting its generic relations. From its general appearance, however, taken in connection with the fact that a few other fresh-water shells occur in the same bed, we are led to regard it as most probably a *Valvata*, though it may possibly be a *Viviparus*, or belong to some marine genus. Its principal distinguishing characters are the small number and ventricose form of its whorls, and strongly defined marks of growth.

Locality and position.—Near southwest base Black Hills, where it was found in loose fragments of a hard bluish-gray argillo-calcareous rock, associated with *Planorbis veternus* and *Unio nucalis*. These masses were found at the base of an outcrop of very similar rock, containing *Ammonites Henryi*, and seem to belong to the same formation. The fresh-water species may be Tertiary, though we think they and the *Ammonite*, with which they appear to be associated, are probably of Jurassic ages. (Type, 316.)

Family VIVIPARIDÆ.

Shell varying from subglobose to turbinate, or conical subovate; rather thin, or more or less thickened, covered with an epidermis; surface smooth, spirally striate, or with revolving, rarely nodose, carinæ; aperture oval or subcircular, simple, and rounded anteriorly; peritreme continuous, simple.

Operculum annular, or rarely with a subspiral nucleus.

Animal retractile within the shell; foot moderate, and adapted for crawling only; rostrum moderate, nearly or quite entire at the extremity; tentacles tapering, retractile, and having the eyes on short tubercular prominences at their outer bases. Gills internal, comb-like, single. Tongue short; lingual teeth in seven longitudinal rows (3. 1. 3), lateral, more or less curved, truncated and serrate, or pointed and claw-shaped at the extremity. Generative organs unisexual; in the male, included in the right tentacle; in the female, under the margin of the mantle on the same side. Female ovo-viviparous.

The following groups are included in this family, viz.: *Viviparus*, *Tulotoma*, *Campeloma* (or *Melantho* of authors; not Bowdich), *Lioplax*, and *Lioplacodes*. The groups *Larina*, *Paludomus*, *Bithynia*, *Bithynella*, *Ganga*, *Tanalia*, *Philopotamis*, and *Rivulina* have also been placed here by some authors, but the labors of Prof. Gill and Dr. Stimpson have shown that all these should be eliminated, thus leaving the *Viviparidæ* probably a strictly ovo-viviparous group.

GENUS VIVIPARUS, MONTFORT.

Synon.—*Vivipare*, LAMARCK, Phil. Zool. 1809, ii. 320 (without example, diagnosis, or figure); and again, in the same way, Extr. d'un Cours. 1812.

Viviparus, MONTFORT, Syst. 1810, ii. 247.—GRAY (in part), Proceed. Zool. Soc. 1847, part xv. 155; and again, Guide to Syst. Distr. Moll. Brit. Mus. 1857, i. 112; GILL, Proc. Acad. Nat. Sci. Phila. 1863, 37.

Henterum, HUBN. Epist. I. 1810.

Paludina, LAMARCK, Extr. d'un cours. 1812 * * *; and Hist. 1822, vi. 172.—SCHWEIGG. (part) Naturg. 1820, 736.—BLAINVILLE (part), Dict. Sci. Nat. 1824, xxxii. 320; and 1825, xxxvii. 300.—DESHAYES (part), Encyc. Meth. 1832, iii. 689, and of various later authors.

Vivipara, SOWERBY, Mineral Conchology, 1813, tab. 31.—H. & A. ADAMS (part), Genera Recent Moll. 1854, i. 38.

Etym.—*Vivus*, alive; *pario*, to bear or bring forth young.

Type.—*Helix vivipara*, LINN.

Shell ovate or conic-subovate, thin, usually with a small umbilical perforation; volutions rounded or more or less flattened; surface smooth or with revolving lines or carinæ; epidermis olivaceous, often with revolving bands of color; aperture more or less regularly ovate; outer lip thin, straight in outline, and continuous on a plane with the inner.

Operculum corneous, entirely annular.

Animal with lateral teeth of the lingual ribbon oblong, arched, somewhat pointed below, truncated and serrate above; median tooth shorter, curved, more or less rounded, and serrate above; the middle denticle being larger than the others.

These mollusks inhabit rivers, lakes, and other bodies of fresh water, and are widely distributed in the Northern hemisphere. This genus is related to *Campeloma*, *Lioplax*, and *Tulotoma*, which have, indeed, until recently, been included in it, either as subgenera or otherwise, by most authors. It may be distinguished from the former two groups, however, by its thinner shell, and by its outer lip being straight in outline and continuous on a plane with the inner, instead of being inversely sigmoid. A more important difference, however, is in the lingual teeth, which, in *Campeloma* and *Lioplax*, have the upper margins smooth, or only very minutely serrated, while the outer two on each side are pointed and claw-shaped, instead of truncated above. *Lioplax* is also distinguished by a subspiral opercular nucleus.

From *Tulotoma* these shells are distinguished by being thinner and not nodular; while the animal of the latter genus is said to have more the habits of *Anculosa*, being found clinging to stones in running water instead of crawling upon the muddy bottoms of sluggish streams and lakes.

This genus is believed to date back as far as the Jurassic epoch. It also occurs in the Wealden deposits, and was well represented during the deposition of all the members of the Tertiary system, at which time the species seem to have been quite as numerous as at present, if not even more so. We already know some six or seven species from the Lignite Tertiary beds of the Upper Missouri and Rocky Mountain regions.

Viviparus Gilli.

(PLATE V, Fig. 3, *a*, *b*.)

Shell small, ovate-subglobose; volutions about four and a half, increasing rather rapidly in size, ventricose, rounded, last one larger than all the others; suture deep and well defined, in consequence of the convexity of the whorls; umbilical chink very small or closed; aperture oval, slightly oblique, and nearly equally rounded above and below, there being but a very slight angularity at the inner side above; peritreme distinctly continuous in adult shells; surface only marked by small, rather obscure lines of growth.

Length of the largest specimen seen, 0.47 inch; breadth, 0.42 inch.

This seems to be a rather rare species, only three specimens having been found, and none of these are entire. It is most nearly allied to the common recent American species *Viviparus lineatus*, Valenc., but is much smaller, and differs in having its aperture more nearly equally rounded above and below. There can be no question about its being a typical *Viviparus*.

We take pleasure in dedicating this oldest known American species to our friend Prof. Theo. Gill, of Washington City, who first pointed out the true distinguishing characters between this and the allied group *Campeloma*, Raf. (=*Melantho* of authors).

Locality and position.—Same as last, where it occurs associated with *Neritella Nebrascensis* and *Lioplacodes veternus*. (Type No. 4035.)

Genus LIOPLACODES, MEEK.

Synon.—*Melania* (sp.), MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. Dec. 1861, p. 444.
Lioplacodes, MEEK, Smithsonian Check List, Jurassic fossils, 1864, 29 and 40.
Etym.—*Lioplax.*
Type.—*Melania* (*Potadoma*) *veterna*, MEEK & HAYDEN.

Shell conoid-subovate, rather thick, scarcely perforate; spire prominent; aperture obliquely subovate, rather obtusely angular behind, and somewhat narrowly rounded and faintly sinuous in front; peritreme continuous; outer lip inversely sigmoid; surface with revolving lines.

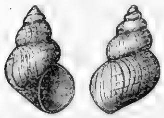
Animal and operculum unknown.

The shell for the reception of which this genus has been proposed is one of those forms presenting an intermediate appearance between the *Melaniidæ* and *Viviparidæ*, so perplexing where we can know nothing in regard to the nature of the animal or operculum. Its comparatively slender subconical form, and the slight flattening of the upper oblique slope of the whorls, together with its revolving lines, give it much the appearance of some types of the *Melaniidæ;* while its small but unmistakable umbilical pit, and continuous peritreme, together with the expression of the aperture, indicate nearer affinities to the *Viviparidæ.* It is perhaps most nearly allied to the genus *Lioplax* of Troschel, but differs from the type of that genus (*Paludina subcarinata*, Say) in having a much less ventricose and proportionally smaller body whorl, more attenuate spire, and numerous thread-like revolving lines, instead of a single carina; while the posterior extremity of its aperture is subangular instead of rounded, in consequence of the oblique flattening of the upper part of the body volution.

Lioplacodes veternus.

Melania (Potadoma) veterna, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. Dec. 1861, p. 444.
Lioplacodes veternus, Meek, Smithsonian Check List, Jurassic fossils, 1864, 29.

Shell with spire elevated; volutions about six, very convex, rounded at the middle, and often obliquely a little flattened above; suture deep; aperture obliquely oval, subangular behind, and rather narrowly rounded and faintly sinuous in front, much more prominent or convex on the outer than the inner side; inner lip disconnected from the columella, so as to leave a small umbilical chink; outer lip broadly sinuous in outline near the middle of the aperture or slightly above, and most prominent below. Surface marked by strong flexuous striæ of growth, which are crossed by more or less distinct thread-like revolving lines, some four or five of which, near the middle of the body whorl, are larger and more widely separated than those below.



Lioplacodes veternus.

Length, 0.77 inch; breadth, 0.50 inch; apical angle convex, divergence about 47°.

This interesting species was at first placed by us, with considerable doubt, in the genus *Melania*, as that group was then understood by most conchologists. The necessity for restricting that name, however, to such forms as *M. amarula*, has become more apparent from late investigations, while the various recent American species resembling our shell have been distributed into several genera. In endeavoring to determine to which of these our species is most nearly allied, by clearing away the matrix with care from about the aperture, it has been found, quite unexpectedly, to present characters, as already stated, showing affinities to the *Viviparidæ*, rather than to the *Melaniidæ.* And yet it differs from the known genera of that family to such an extent that it has been thought desirable to regard it as the type of a new genus.

Locality and position.—Head of Wind River, Dakota Territory, from beds referred provisionally to the Jurassic system. Associated with *Neritella Nebrascensis.* (No. 1978.)

Class CEPHALOPODA.

Order Tetrabranchiata.

Family AMMONITIDÆ.

Shell involute, spiral, variously curved, or straight; outer or last chamber large. Aperture varying in form with the genera and species; lip often more or less produced on the outer or dorsal side, sometimes hooded, or provided with lateral appendages. Septa more or less deeply lobed on the margins; presenting a convex outline (in their mesial section) on the side facing the aperture; lobes variously plicated or sinuous and dentate or merely serrated on the margins. Siphon dorsal, with relation to the shell, cylindrical, slender, never occupied by an internal organic deposit, piercing the septa from within outwards, or towards the aperture; envelop solid and persistent.

Animal unknown, all the genera of the entire group being extinct.

This family is nearly related to the *Goniatitidæ*, through the intermediate Ceratites. Indeed, previous to the researches of the distinguished palæontologist Barrande, the Goniatites were by most authors, along with the Ceratites, included in the family *Ammonitidæ;* and some even included these three genera under the single generic name *Ammonites.* M. Barrande, however, has shown (Bul. Geol. Soc. Fr. 2, ser. t. xiii, p. 375, 1856) that the *Goniatite* group differs from the true *Ammonitidæ*, not only in the greater simplicity of their septa, but also in having the neck or gullet of the siphon always projecting backwards, as in the *Nautilidæ*, instead of forwards, or towards the aperture, as in the *Ammonitidæ.* Again, he finds that a mesial section of their septa shows a concave, instead of a convex, outline on the side facing the aperture; while their siphonal envelop is not solid and persistent, as is usually the case with *Ammonitidæ.*

From these facts some authors have gone to the opposite extreme, and included the *Goniatite* group in the *Nautilidæ.* M. Barrande, however, has shown, in the paper above cited, that at the same time that they agree with the latter family in these several characters, they still differ in some important elements of structure. In the first place, they always differ in having the septa provided with a dorsal lobe, and generally in having their septa more lobed or sinuous on the sides. Another important difference is the entire absence of the peculiar organic deposit within the siphon, such as we sometimes see in extinct forms of the *Nautilidæ.* Again, they differ in having the siphon invariably on the outer side, instead of varying in its position between the dorsal and ventral margins. Hence we are inclined to agree with M. Barrande in separating these cephalopods into the three distinct families, *Nautilidæ*, *Goniatitidæ*, and *Ammonitidæ.*

It is an interesting fact that, even after excluding the *Goniatite* group from the family *Ammonitidæ*, we still have a very extensive and varied group of shells, amongst which we observe a representative, so far as form is concerned, of nearly every genus, not only of the *Nautilidæ*, but also of the apparently distinct *Orthoceras* group. This fact would seem to argue, either that the *Nautilus* and *Orthoceras* groups should not be separated, or that there may be genera belonging to more than one family included in the *Ammonitidæ*, even as here defined. Still, notwithstanding the great differences of form observed amongst these fossils, they agree so very nearly in their internal structure, that it seems difficult, in the present state of our knowledge, to point out constant characters by which they can be divided into distinct families, or even well-defined subfamilies.

When we take into consideration the infinite diversity of beautiful forms presented by the shells of these mollusks, their great numbers, and often elaborately ornamented surface, and remember the large sizes to which they sometimes attained, it is easy to understand that they must have constituted a marked and peculiar feature of the molluscan fauna of the Jurassic and Cretaceous seas.

It not unfrequently happens, where the substance of the shell is well preserved, that in breaking specimens from the rocky matrix in which they are enveloped, the outer porcellaneous layer exfoliates, leaving the elegantly sculptured surface of the fossil covered with the brilliantly iridescent inner pearly layer, in which condition they form exceedingly beautiful cabinet specimens. It is necessary, however, to remove this inner layer also, when we wish to study the complex internal structure of the shell, which furnishes important characters for the distinction of species and sometimes of genera.

The following are the genera we would at present include in this family, viz: *Baculina*, *Baculites*, *Ptychoceras*, *Hamulina*, *Hamites*, *Toxoceras*, *Crioceras*, *Ancyloceras*,[1] *Scaphites*, *Ceratites*, *Ammonites*, *Anisoceras*, *Helicoceras*, *Heteroceras*, and *Turrilites*. It seems to be impossible, however, by a linear arrangement, to place these groups so as always to bring together those most nearly allied.

REMARKS ON THE SO-CALLED GENUS TRIGONELLITES, OF PARKINSON, 1811.

Aptychus, MEYER, 1831.—*Ichthyosyagon*, BOURDET, 1822.—*Munsteria*, DESLONGCHAMPS, 1835.

A consideration of the family *Ammonitidæ* would scarcely be complete without some allusion to those curious bodies generally known by the names *Trigonellites*, *Aptychus*, &c., so often found within, or associated with, the shells of the typical genus. Few objects amongst all the relics of extinct life have been more puzzling to the palæontologist, or given rise to a greater diversity of opinions than these. Most of the early palæontologists regarded them as the shells of bivalve mollusks, as did Parkinson, Deslongchamps, and some later investigators; while others supposed them to be the palatal bones of fishes. Others, again, maintained that they are the internal osselets of some extinct cephalopod allied to *Teudopsis;* and still others, that they are an internal organ of Ammonites, analogous to that connected with the digestive apparatus of *Bulla* and some other *Gasteropoda.* Burmeister supposed them to be external supplementary shell pieces of Ammonites, designed for the protection of the branchial sack when the animal was partly protruded from the shell. More recently, D'Orbigny, Pictet, and some others have advocated, with much ingenuity, an opinion first suggested by Scheuchzer, that they are the valves of pedunculated Cirripedes allied to *Anatifa.*

The impression, however, has for some time been gaining ground amongst palæontologists that these bodies really are organs or appendages of the Cephalopods, with the shells of which they are so frequently found associated. And since Darwin

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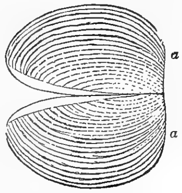
[1] It is possible the genus *Ancyloceras* may be synonymous with *Crioceras,* since the species for which the latter genus was proposed have never, we believe, been found entire; and it yet remains to be clearly demonstrated that *Ancyloceras* was not founded upon perfect specimens of the same type. If so, the name *Crioceras* will take precedence, because it was published in 1836, and *Ancyloceras* in 1842.

has shown that it is against all analogy to regard them as the valves of Cirripedes,[1] the most generally received opinion is that they are the opercula of Ammonites, Scaphites, Goniatites, &c.[2] This opinion would also seem to receive considerable weight from the discovery, in few rare instances, of an Ammonite with a Trigonellite closing and apparently exactly fitting its aperture.[3]

Before bringing forward some reasons, however, for doubting the correctness of this conclusion, suggested by a remarkable Trigonellite found in a Scaphite from the Cretaceous rocks of the Upper Missouri country, the following description of this provisional genus is necessary for a clear understanding of the subject:—

As usually found, these bodies consist of one or two (most frequently two) ovoid or subtrigonal plates or valves, with one extremity truncated and generally wider than the other, and one side nearly or quite straight; while the outer or lower surface is a little convex, and the inner concave. Unless displaced or separated by some accidental cause, the two pieces always occur with the straight edges joined together in such a manner as to indicate that they were originally held together in some way. The normal position of the two pieces seems to be like that of the valves of a bivalve shell partly open; but when they are opened out and flattened by pressure, as is often the case, they frequently present the bilobate appearance seen in the annexed cut, Fig. 1. In structure, composition, and thickness they present differences, in consequence of which the group has been divided into the three following sections:—

Fig. 1.



1. The Cellulosi, which are thicker than those of either of the other sections, and consist first of a thin, concentrically striated inner layer, over which there is a thick calcareous portion, composed of numerous polygonal tubes arranged with their longer axes at right angles to the outer and inner surfaces of the valves. Outside of this there is a thin calcareous layer, the smooth surface of which is usually perforated by small pores.
2. The Imbricati, with an inner layer like the preceding, and a middle porous stratum, the tubes of which are smaller and less distinctly defined. Its outer layer also differs in being a true calcareous shell, with distinct plications, and a smooth punctate surface, the punctæ of which are arranged in regular lines.
3. The Cornei, which are said to consist of a single very thin corneous lamina, destitute of any porous or tubular layer.

Our Upper Missouri specimen, already alluded to, is very thin, and seems to be composed of a single lamina showing no cellular structure, and may consist only of the inner layer. It occurs in the outer chamber of a *Scaphites Cheyennensis*, and is the only organic body found in it, the surrounding space being filled with the fine indurated sedimentary matter, similar to that in which the Scaphite was originally enveloped. It occupies a position apparently about one-fourth of the distance back from the aperture to the first septum, and lies with the two valves partly open, and apparently in their natural position with relation to each other, their straight edges being joined together, and deflected upwards so as to form a distinct carina, which

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[1] The reason offered by Mr. Darwin for rejecting the conclusion that these bodies are the valves of a Cirripede is, that they are nearly always found with the straight edges of the two valves or pieces in contact, so as to show that they must have been anchylosed or held together by a membrane or kind of ligament along these margins, which would have been impossible if they were the valves of a Cirripede, since that is the very side where the feet would have to pass out.

[2] They have been found associated with Goniatites in Devonian rocks.

[3] See an example published by Mr. Woodward in the Geologist, vol. III, 1860, p. 328.

comes in contact with the so-called dorsal (properly ventral) side of the Scaphite; while the truncated ends of the valves (Fig. 1, *a*, *a*, which represents the valves of this specimen as it would appear if opened and flattened out) are directed forward towards the aperture.

The fact, however, to which we would call especial attention, is the occurrence of a third piece or appendage, differing entirely in form from either of the two valves already noticed, and, so far as we know, from anything hitherto found in connection with any of these fossils. This third piece occupies a position between the two valves as they lie together, partly opened; being nearer the extremity directed towards the aperture of the shell, and exactly fitting between the valves, as if in its normal position with relation to them. It is thin, and agrees so exactly, in color, texture, and surface markings, with the two valves enveloping it, that it is impossible to examine the specimen for a moment and entertain a doubt in regard to all three of these pieces being parts of the same fossil.

The appendage to which we allude differs entirely from the usual form of a Trigonellite or Aptychus, as generally understood, and presents a very peculiar jaw-like appearance. It consists of a single piece, with two thin rami or lateral expansions extending backwards so as to present, when viewed on either side, the outline and appearance of the annexed cut, Fig. 4; while Fig. 3 represents its upper side. Its two lateral expansions, however (*a*, *a* of Fig. 3, and *c* of Fig. 4), have their upper margins inflected so as to appear, as seen from above, to be thicker than they really are. The position of this third piece between the two valves will be understood by reference to Fig. 2, the right end of the figure being that directed towards the aperture of the shell, and the lower or straight side being in contact with the so-called dorsal side of the same.

Fig. 2.

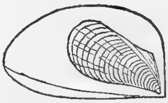


Fig. 3.

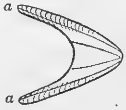
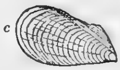


Fig. 4.



The presence of this third part or appendage would seem to furnish another strong argument, if any were necessary, against the conclusion that these fossils are the valves of Cirripedes, since its form is such that it can scarcely be regarded as homologous with any of the external plates of those animals. Its form, if not indeed its very existence, seems, we think, even more irreconcilable with the rather generally accepted opinion that they are opercula. We can readily understand how the two valves might be opened out and attached to a fleshy lobe, or some of the softer parts of the animal, so as to perform the offices of an operculum; but it seems impossible to conceive how this third jaw-like piece, which is manifestly a part of the same fossil, could be in any way connected with such an organ. In addition to this, it may be added that many Ammonites are known to have the aperture at maturity so remarkably contracted or modified by the development of lateral appendages of the lip, that it appears almost impossible that they could have been provided with an operculum.

In examining the curious third appendage described above, one can scarcely fail to be impressed with its resemblance to a jaw or beak. Indeed, so striking is this analogy, that we are strongly inclined to adopt that conclusion, notwithstanding the fact that we must then view the two[1] enveloping valves as forming together one of the opposing mandibles. The opinion that these bodies may be jaws instead of opercula—first suggested by Van Bréda, if we mistake not—receives additional support from the entire absence, so far as known, of anything else representing jaws or beaks, within the thousands of *Ammonites* that have been broken open in various parts of the world; while all the existing *Cephalopoda* are known to be provided with such oral organs. Again it will be remembered, that in the living *Nautilus* (the beaks of which are partly calcareous, and partly corneous), the upper mandible is received within, and enveloped by, the lower, much as the appendage we have described lies between the valves in our specimen.

Genus AMMONITES, Bruguiere.

Synon.—*Ammonites*, Bruguiere, Encyc. Meth. I, 1789, xvi and 28.—Lamarck, Prodr. 1799, 80; Syst. Ann. 1801, 100; Phil. Zool. 1809, 323.—Feruss. Tab. Syst. 1819.—Roissy, Mol. V, 1805, 16, &c.
Planulites, Montfort, Conch. Syst. I, 1808, 78; (not Lamk. 1801 ?; nor Munster, 1832.)
Ellipsolithes, Montf. ib. 86.
Argonauta, Reinecke, Mar. proto. Naut. 1818, * * * (not Lin.).
Ammonita, Gray, Lond. Med. Rep. 1821.—Fleming, Brit. Ann. 1828, 240.
Etym.—*Ammon*, a name of Jupiter.
Examp.—*Ammonites bisulcatus*, Bruguiere.

Shell discoidal or more or less convex, sometimes subglobose. Volutions contiguous or embracing at all stages of growth, and coiled in the same plane; umbilicus varying greatly in breadth and depth with the species. Surface costate, nodose, subspinous, striate, or smooth. Lip simple, inflected, or with various lateral appendages. Lobes and saddles of the septa more or less branched and deeply divided; the margins of the subdivisions sinuous and dentate.

In form, the dorsal position of the siphon, and often in ornamentation, the Ammonites present scarcely any difference from the Ceratites and Goniatites. They differ from the latter, however, in having the lobes and saddles of the septa divided and variously branched or dentate, instead of simple. From the former they often present but slight and scarcely perceptible differences, even in the septa, the lobes of which only differ in being more or less deeply divided and branching, instead of merely serrated on their margins. There are, however, some intermediate species connecting these groups, so that even palæontologists do not always agree in regard to their position.

The Ammonites are also related to the genus *Scaphites*, from which they only differ in not having the last or body whorl of the adult shell deflected from the

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[1] It is worthy of note in this connection, that M. Coquand has maintained that an Aptychus (as hitherto understood) properly consists of a single piece—that the apparent existence of two distinct valves, is produced by the fracture of a single flexed plate, along a mesial line of least resistance, from accidental pressure.

regular curve of the inner turns, and the aperture again turned back towards the body of the shell. In the position of the siphon, the structure of the septa, and in ornamentation, there is no difference between these groups; and it was probably only at maturity that the shell of a Scaphite differed from that of an Ammonite, while in some species this difference is very slightly marked.

The genus *Ammonites*, as here defined, was introduced at near the close of the Triassic epoch, though several authors improperly refer to it some of older Goniatites.[1] It is very numerously represented through the Jurassic and Cretaceous series, some eight hundred or more species having been already described from these rocks. As might be expected, the species of so large a group present great diversities of form and ornamentation, and various attempts have been made to group them into sections or subgenera, without any great degree of success. When we observe the remarkable differences, however, presented by the form of the aperture, and the labial appendages of some of the species when found entire, we are led to suspect that we may some time be able to separate them into several natural groups, either having the rank of genera or subgenera. We have no authentic evidence of the existence of this genus after the close of the Cretaceous epoch.

Ammonites cordiformis.

(PLATE V, Fig. 2, *a*, *b*, *c*, *d*, *e*.)

Ammonites cordiformis, MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. March, 1858, 57; ib. Oct. 1860, 418.

Comp. *A. cordatus*, SOWERBY, Min. Con. vol. I, 1812, 51, 17, figs. 2–4; also D'ORBIGNY, Pal. France I, pl. 193; Geol. Russia, pl. 34, figs. 1–5.

Shell lenticular, adult specimens being much more convex than the young; umbilicus rather small, or from one-third to one-halt the breadth of the outer whorl; dorsum carinate; volutions increasing so as to more than double their diameter every turn, each of the inner ones from one-half to three-fourths hidden within the ventral groove of the succeeding whorl. Surface ornamented by numerous small flexuous costæ, which, in crossing the sides, increase by division and intercalation so as to number two or three times as many at the periphery as around the umbilicus. In approaching the dorsum, they curve forward, and all cross the dorsal carina, to which, in young specimens, they impart a distinctly crenate outline.

Greatest diameter of a specimen divested of its outer whorls, 3.30 inches; diameter of its last turn, from umbilicus to dorsum, 1.63 inch; breadth of same, 1.46 inch.

The septa are not very closely crowded, and have each five lobes on either side, none of which are deeply divided, or very complex in their details. The dorsal lobe is a little wider than long, and has two principal branches on either side, the two terminal of which are slightly larger than the others, and each provided with seven or eight unequal digitations. The dorsal saddle is about the size of the superior lateral lobe, contracted in the middle, and divided at the extremity into some four or five short, unequal, sinuous, and digitate branches. The superior lateral lobe is as long as the dorsal lobe, but narrower, conical in form, and ornamented with three or four lateral branches on the dorsal side, and two or three smaller ones on the ventral side; while its terminal branch is bipartite, and its margins, as well as those of all the other principal divisions, are more or less sinuous and digitate. The lateral saddle is smaller than the superior lateral lobe, and has on each side three or four very short, obtuse subdivisions, with sinuous margins. The inferior lateral

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[1] The species in the Upper Trias have more simple septa, and often closely approach the genus *Ceratites* in this respect.

lobe is smaller than the lateral saddle, and divided at the extremity into two nearly equal, rather short branches, each of which is sinuous, and shows a disposition to give off short subdivisions on the outer side. The remaining lobes are very small, and obtusely digitate, the inner one showing a tendency to bifurcate.

This species varies considerably in form, as well as in its surface markings, at different ages; young specimens being much more compressed, more sharply carinate on the dorsum, and having a proportionally wider and more shallow umbilicus than the adult. Their costæ are also more flexuous and more sharply elevated than those of mature shells. On medium-sized specimens the costæ that pass entirely across the sides sometimes swell a little near the umbilicus, so as to form very obscure, transversely elongated, subnodose prominences; while on large specimens all the costæ are nearly or quite obsolete.

If *Ammonites cordatus*, of Sowerby, varies as much as it would seem to do from the figures of it given by D'Orbigny in the Palæontology of France, and in Murchison, De Verneuil, and Keyserling's work on the Geology of Russia, our shell may prove to belong to that species. In form and external ornaments it is almost exactly like some varieties of *A. cordatus*, yet it presents rather marked differences in its septa from any of the figures of that species we have seen; not greater, however, than we see between the septa of supposed individuals of that extremely variable form, represented by D'Orbigny in the Pal. France, and in the Geol. Russia. Although later comparisons have nearly satisfied us that our shell is not distinct from Sowerby's species, we have concluded to retain our name, *cordiformis*, until its identity or difference can be determined by the comparison of a better series of specimens.

Locality and position.—Southwest base of the Black Hills, associated with *Belemnites densus*, *Eumicrotis curta*, and other Jurassic fossils. (Type No. 203.)

Ammonites Henryi.

(Plate IV, Fig. 9, *a*, *b*, *c*,)

Ammonites Henryi, Meek & Hayden, Proceed. Acad. Nat. Sci. Phila. March, 1858, 57; ib. Oct. 1860, 418.

Shell convex-lenticular; dorsum narrowly rounded or subangular; umbilicus very small or nearly closed. Volutions about doubling their diameter every turn; inner ones entirely hidden within the profound ventral groove of each succeeding whorl. Surface apparently without nodes or costæ.

The septa are rather closely crowded, but their lobes and saddles are not very deeply sinuous, or complex in their subdivisions, and differ somewhat in their details on opposite sides of the shell. None of our specimens are in a condition to show very clearly the whole of the dorsal lobe, though it appears to be as long as the superior lateral lobe, and has at the extremity two small approximate terminal divisions, each of which is provided at the end with three or four small digitations; above these there is on each side one broad, but short, bifurcating, and more or less digitate lateral branch, and, above that, one or two subordinate lateral sinuosities. The dorsal saddle is about as large as the superior lateral lobe, a little oblique, and has at the extremity two short, nearly equal, digitate divisions, each of which shows a tendency to bifurcate. Below these there is on each side one lateral branch. The superior lateral lobe is as large as the dorsal, somewhat obliquely conical, and tripartite at the extremity, the divisions being small, subequal, divergent, and merely digitate; above these there is on the dorsal side one digitate lateral branch, and on the ventral side one or two lateral digitations. The lateral saddle is much smaller than the dorsal saddle, more or less oblique, and ornamented at the extremity by some five or six very short, palmately spreading, obtuse divisions. The inferior lateral lobe is as wide, but scarcely half as long, as the superior, and on one side of the shell divided to its very base into two small, nearly equal, digitate parts; while on the other side of the shell it is narrower, and tripartite. Between this and the umbilicus there are about three very small, rather distant, digitate ventral lobes.

This species is quite distinct, in the structure of its septa, from all the other Ammonites yet known in any of the Nebraska rocks, and we are not acquainted with any nearly allied forms amongst foreign species. The only specimens of it we have seen are somewhat distorted, and consist of the inner septate whorls. One of these measures 3.10 inches in its greatest diameter, and 1.33 inch in breadth.

The specific name was given in honor of Prof. Joseph Henry, Secretary of the Smithsonian Institution.

Locality and position.—Southwest base of the Black Hills, in the upper Jurassic rocks of that region. (No. 314.)

ORDER **Dibranchiata.**

SUBORDER DECAPODA.

FAMILY BELEMNITIDÆ.

Shell (internal) consisting of a somewhat nacreous pen, expanded in front, and terminating posteriorly in a thin chambered cone, with simple septa, called the *phragmocone*, which is sometimes enveloped in a strong subcorneous or calcareous guard, having a radiated semi-fibrous structure. Chambers of the *phragmocone* connected by a ventral siphon.

Although this family is entirely extinct, specimens of one of the genera (*Belemnoteuthis*) have been found in such a state of preservation as to give a tolerably correct idea of the softer parts of the animal. From these it has been ascertained that it was provided with arms and tentacles of nearly equal length, armed with corneous hooks. The mantle was free all around, and the fins medio-dorsal.

This family embraces the genera *Belemnites*, *Xiphoteuthis*, *Belemnitella*, *Acanthoteuthis*, *Belemnoteuthis*, *Conoteuthis*, and *Helicerus*.

Genus BELEMNITES, AUCT.

Synon.—*Belemnites*, LISTER, 1678, and (in whole or part) of various other pre-Linnæan authors.—SCHROTER (part ?), Lith. Lext. 1779, i. 151; Vollst. Einl. 1784, IV, 149.—ROISSY (part), Moll. V, 1805, 43.—CUVIER (part), Regn. An. 1817, 371.—D'ORBIGNY, Palæont. Fr. Ter. Cret. 1, 1840, 37; An. Sci. Nat. XVII, 1842, 241; Moll. Viv. Et. Foss. I, 18 * * ?, 459 and of many later writers. (Not *Belemnites*, LAMARCK, Prodr. 1799, 81; nor Syst. An. 1801, 104; nor An. Sans Vert. 1822, VII, 590, which is *Belemnitella*, D'ORBIGNY.)
Paclites, MONTFORT, Conch. Syst. I, 1808, 318.
? *Thalamus*, MONTF. 1808, ib. 322.
Achelois, MONTF. 1808, ib. 358.
Callirhœ, MONTF. 1808, ib. 362.
Cetosis, MONTF. 1808, ib. 370.
Acamas, MONTF. 1808, ib. 374.
? *Chrysaor*, MONTF. 1808, ib. 378.
Hibolithes, MONTF. 1808, ib. 386.

Porodragus, MONTF. 1808, ib. 390.
Belemnita, FLEMING, Brit. Anim. 1828, 240.
Notosiphites, DUVAL-JOUVE, Belemn. 1841, 64.
Gastrosiphites, DUVAL-JOUVE, ib.

Etym.—Βέλεμνον, a dart.
Examp.—*Belemnites Puzosianus*, D'ORBIGNY.

Pen consisting of two parallel, nacreous, sword-snaped processes, extending forward from the anterior dorso-lateral margins of the phragmocone. Guard elongated, cylindrical, more or less clavate, or somewhat compressed; becoming very thin anteriorly, where it is pierced by a deep conical cavity with entire margins, for the reception of the phragmocone; solid and more or less pointed at the posterior extremity. Phragmocone often terminating in a minute bulb at the apex; septa nearly horizontal, concave; siphon contracted where it passes through the septa, and somewhat expanded between them.

Animal unknown.

The guards of Belemnites, popularly called "thunderbolts," are the part most frequently met with. They generally have a semi-translucent, somewhat horny appearance, and a fibrous structure, the fibres radiating from a longitudinal, subcentral line. It varies greatly in form and size in the different species and varieties, as well as, apparently, in the two sexes. Sometimes it only extends about half an inch beyond the phragmocone, while in other instances it attains a length of one or two feet. It is readily distinguished from the guard of the allied genus *Belemnitella* by the absence of a slit down the anterior wall of the pierced end, and by having no distinct vascular markings on the ventral side. It also wants the flattened ridge always seen on the dorsal side of well preserved specimens of *Belemnitella*.

The genus has been divided into the following sections and subsections:[1]—

SECTION 1. **Acœli**, BRONN. Without dorsal or ventral grooves.
- a. *Acuarii*, without lateral furrows, but often channelled at the extremity. (Lias and Neocomian).
  Type.—*B. acuarius.*
- b. *Clavati*, with lateral furrows.
  Type.—*B. clavatus* (Lias).

SECTION 2. **Gastrocœli**, D'ORBIGNY. = **Notosiphites**, DUVAL. Ventral groove distinct.
- a. *Canaliculati*, no lateral furrows. (Oolites.)
  Type.—*B. canaliculatus.*
- b. *Hastati*, lateral furrows distinct. (Upper Lias and Gault.)
  Type.—*B. hastatus.*

SECTION 3. **Notocœli**, D'ORBIGNY. = **Gastrosiphites**, DUVAL. With a dorsal groove and furrow on each side.
Type.—*B. dilatatus* (Neocomian).

The great numbers of the guards of Belemnites often found imbedded together in the same stratum indicate that these mollusks were gregarious in their habits, and they are supposed to have preferred muddy bottoms. The genus made its appearance near the beginning of the Liassic epoch, during which it seems to have attained its greatest development. It continued, however, to exist until about the middle of the Cretaceous period.

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[1] Woodward's Man. Mol. p. 74

The synonymy of this genus is involved in some obscurity. We have not been able to consult all the works in which the name was used, between the establishment of the binomial system by Linnæus, in his 10th ed. Syst. Nat. 1758,[1] and the publication of Lamarck's Prodrome, in 1799. Consequently we have no means of determining, beyond doubt, whether or not any of these authors used it in accordance with the established usages of the Linnæan nomenclature before Lamarck. It is highly probable, however, that they did not; and if any of them did, it is more than probable they included both groups—that is, *Belemnites*, as usually understood, and *Belemnitella*, D'Orbigny. In the first case, Lamarck would be the first binomial author that used it, and hence the author of the genus; and in the second case, he would be the first to select the type of the genus. In first using the name in 1799, he gave a diagnosis, but mentions no type or example. In 1801, however, he uses exactly the same diagnosis, and mentions *B. paxillosus* (referring to Breynius's figures) as his only typical example. As this example, beyond doubt, belongs to the type long afterwards named *Belemnitella*, it follows that if we regard Lamarck as the author of the genus, or as the first to select its type, that the name *Belemnites* will have to be retained for the *Belemnitella* group. If so, then Montfort's name, *Paclites*, 1808, would have to be used for the group here described, and the name of the following species would have to be written *Paclites densus.* Not having the necessary works at hand to clear up all these doubtful questions respecting the synonymy of this genus, we have concluded to use for the present at least, the generally accepted name *Belemnites* for this group.

Belemnites densus.

(PLATE IV, Fig. 10, *a*, *b*, *c* and Pl. V, 1, 1*a*, *b*, *c*. *d*, *e*, *f*, *g*, *h*.)

Belemnites densus, MEEK & HAYDEN, Proceed. Acad. Nat. Sci. Phila. March, 1858, 58; ib. Oct. 1860, 418.

Shell or guard large and thick, subcylindrical, more or less compressed laterally, the cross section having a slightly oval outline. Lower portion tapering to a point; sometimes a little oblique, usually more compressed than any part above; rarely having, at the immediate point, a narrow, obscure groove on the ventral side, and a very slight carina on the dorsal side. Surface smooth. Alveolar cavity apparently extending about half way down from the summit, and terminating nearly midway between the centre and the ventral side; from this point the axial line passes down, gradually approaching the ventral margin, but curving slightly, so as not to intersect it before reaching the extremity. Phragmocone very slightly curved; apical angle 20°. Septa rather closely arranged, about twenty of them occurring in a section one inch in length, measuring 0.72 inch in diameter at the larger end, and 0.35 inch at the smaller extremity; siphon unknown.

The most nearly complete specimen of the guard we have seen measures 5 inches in length, and 0.90 inch in diameter at its larger end. The alveolar cavity of this specimen is 2.39 inches in length, and 0.75 inch across at the aperture, which is slightly oval. Some fragments in the collection, however, appear to have belonged to individuals at least one-third larger than that from which these measurements were taken.

This Belemnite is very closely related, in most of its characters, to *B. Panderianus*, D'Orbigny, as figured in Murchison, De Verneuil, and Keyserling's work on the geology of Russia, vol. 2, pl. 30. The only differences we have observed are that

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[1] Linnæus never adopted *Belemnites* as a generic name, but merely used it as a kind of specific name, under *Helmintholithus*, in which he included nearly all kinds of fossils. See Syst. Nat. xii. ed., 1768, iii. 162. Gmelin used it in the same way in xiii. ed. Syst. Nat. iii. 413.

the section of all our larger specimens is more nearly circular, and they appear never to possess the broad, shallow groove represented by D'Orbigny's figures, on the ventral side, near the apex. Some individuals have on that part of the shell a linear groove, but it seems never to widen upwards as represented in *B. Panderianus.* There is also on some of our larger specimens a slight carina near the apex of the dorsal side (Fig. 1*g*, Pl. V), not represented by D'Orbigny's figures, nor mentioned in his description.

Along with these large specimens we find several smaller ones, having a proportionally more slender form, and a more nearly central axial line. Some of these also have a quite distinct, though narrow, ventral groove (Figs. *d*, *e*, *f*, Pl. V), while their transverse section varies from subcircular to oblong-oval. These, we suspect, belong to a distinct species, but, without better and more extensive collections for comparison, we have not been quite able to satisfy ourselves they may not be younger individuals of the more robust form. These two varieties appear to bear exactly the same relations that the large and small specimens of *B. Panderianus* figured by D'Orbigny do to each other.

Locality and position.—Southwest base of the Black Hills, associated with *Eumicrotis curta*, and other Jurassic fossils. (Type, No. 195.)

SUBKINGDOM ARTICULATA.

CLASS **ANNULATA.**

ORDER **Tubicola.**

FAMILY SERPULIDÆ.

Enveloping tube more or less calcareous, or membranaceous.

Animal vermiform, rounded or somewhat compressed; segments short. Head lobe soldered to the oral segment, and not distinct in the adult. Oral segment with a pencil of setæ on each side, and generally provided with a collar. Mouth directed forward, without a proboscis, situated between the bases of the branchial plumes. Branchiæ two, one on each side, either semicircular, circular, or spirally coiled; consisting of a basal membrane, from the anterior margin of which the threads arise, either in a single or double row. Setæ simple and of two kinds, capillary or hooked.

The recent genera included in this family are *Anisomelus*, *Sabella*, *Eriographis*, *Protula*, *Serpula*, *Spirorbis*, *Filograna*, and *Fabricia.*

The fossil forms described under the names *Hamulus*, *Spirulœa* (or *Rotularia*), *Cyclogyra*, *Serpulites*, *Trachyderma*, &c., probably also belong to this family.

Genus SERPULA, LINNÆUS.

Synon.—*Serpula*, LINNÆUS, Syst. Nat. 10th ed. 1758, 786; ib. 12th ed. 1767.—BRUG. Encyc. Meth. I, 1792, xiv.—LAMARCK, Syst. An. 1801, 325.—BLAINV. Dict. Sci. Nat. XLVIII, 1827, 549, &c.

Etym.—*Serpo*, to creep.

Examp.—*Serpula vermicularis*, LIN.

Tube calcareous, procumbent, variously curved or spirally coiled, growing singly or in groups, attached to marine bodies; capable of receiving the entire animal. Aperture at the larger extremity simple and rounded.

Animal without feet; mouth not provided with tentacles. Branchiæ large, pectinated, flabellate, with bearded lacinæ, and a cylindrical filament at the base of each, differing in length in each of the branchiæ, the longer sustaining an orbicular disk, or funnel-shaped operculum.

This genus is closely related to *Spirorbis*, which some authors include as only a section of the same group. As these two types, however, differ in their branchiæ, as well as in the regularly coiled, *Planorbis*-like form of the tube of *Spirorbis*, they are doubtless distinct genera.

The shells of these Annelids were formerly supposed to be those of true mollusks, but as soon as naturalists examined the animal inhabiting them, it was found to belong to the *Articulata*. Where we only know the shelly tubes, however, as is of course always the case with the extinct species, it is very difficult to distinguish species of this genus, not merely from the allied genera, but even from *Vermetus*, a true mollusk. Consequently much confusion exists in the classification of the fossil species, and for the same reason the geological range of the genus is not well determined. Some authors refer to it Devonian, and even Upper Silurian species; but it is quite probable that if we had any means of ascertaining the nature of the animals once inhabiting these shells from the older rocks, they would be found to all differ generically from the more modern and existing Serpulas. The number of supposed Serpulas is found to increase as we ascend through the Carboniferous and later deposits, and the genus appears to attain its maximum development at the present time. The recent species are numerous, and attach themselves to stones, shells, pieces of wood, the bottoms of ships, &c., and are widely distributed.

Serpula (UNDT.)

(PLATE V, Fig. 4.)

Tubes growing in small groups, irregularly curved, slender, increasing gradually in size; having a distinct carina along the middle above, and a more obscure angle along each upper outer side, so as to give a subquadrate external form to the transverse section. Under side flattened, and inclined to spread out a little on the surface to which it is attached. Aperture and transverse section of interior circular. Surface apparently smooth, or only having very obscure marks of growth.

Length, apparently, never more than about 2 inches; greatest diameter, about 0.15 inch.

This species resembles rather closely some of the Jurassic forms figured by Goldfuss and others; but all our specimens being worn or weathered so as to obliterate, to a great extent, the more delicate surface characters, we do not feel warranted in identifying it with any foreign species, nor are we clearly satisfied that it is new.

Locality and position.—Southwest base of the Black Hills. Lower part of the Jurassic rocks of that region. (Type, No. 219.)

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PUBLISHED BY THE SMITHSONIAN INSTITUTION,
WASHINGTON, D. C.
APRIL, 1865.

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- 11 *a.* Side view of a cast of left valve. The drawing of this figure is not accurately copied in the lithograph, it represents the beak too prominent, and too attenuate, in consequence of the antero-ventral margin not being made sufficiently prominent.
- 11 *b.* Dorsal outline profile of same.

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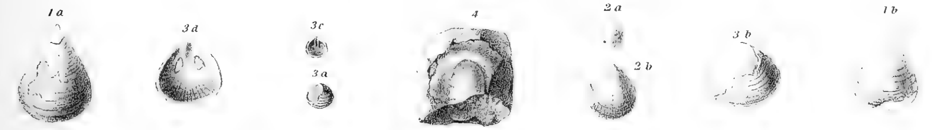
PRIMORDIAL OR POTSDAM PERIOD.



CARBONIFEROUS PERIOD.

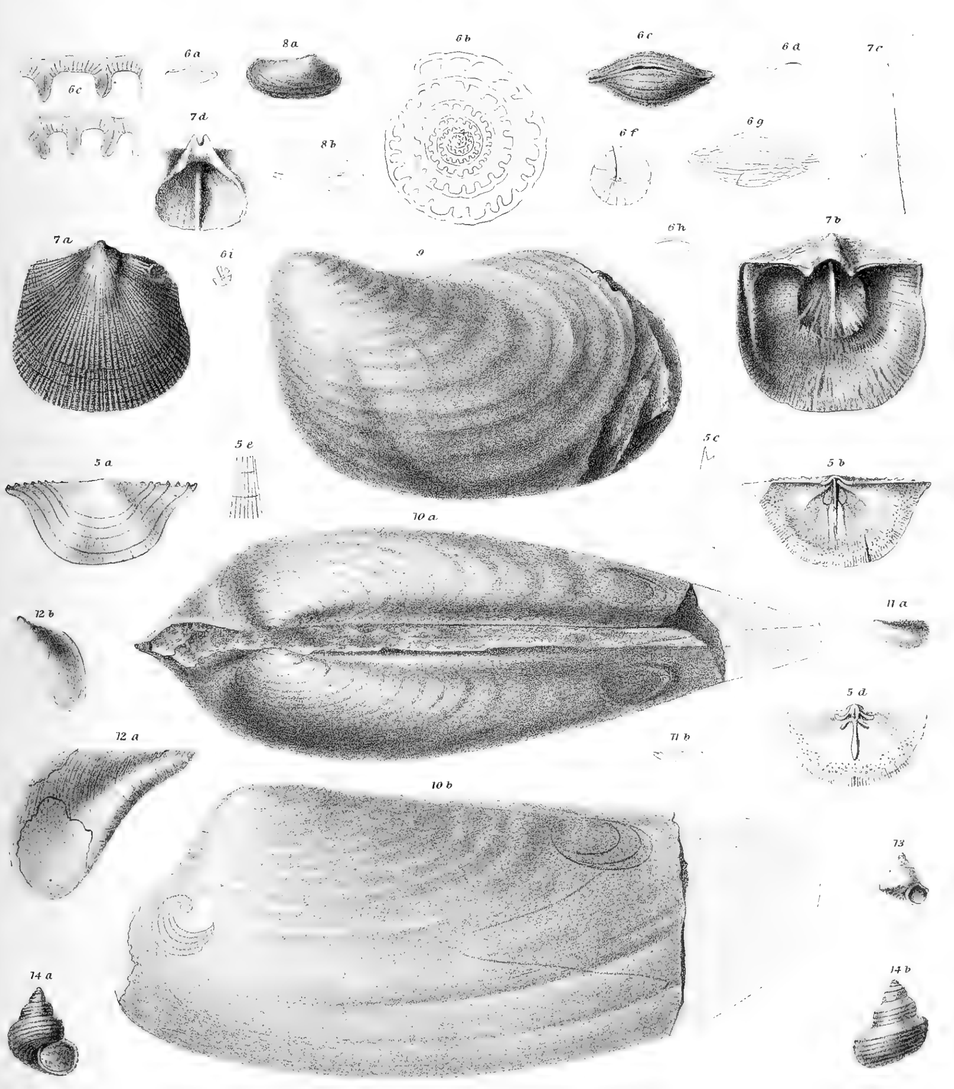


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Fig. 1. *a, b, c.* . . . Chænomya leavenworthensis. 43

1 *a.* Side view, with portions of the shell removed, so as to show the muscular scars, and faintly sinuous pallial impression.
1 *b.* Dorsal view of an internal cast, showing the wide posterior gap.

Fig. 2. *a, b.* . . . . . Chænomya Cooperi. 44

2 *a.* Side view of a cast, with a little of the posterior margin broken away.
2 *b.* Dorsal view of same, showing a distinct depression along the hinge left by an internal thickening of the cardinal margin.

Fig. 3. . . . . Pleurophorus? subcuneata. 61

Fig. 4. *a, b.* . . . . . Yoldia subscitula. 60

4 *a.* Side view of a cast, left valve.
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5 *a.* Internal cast of a left valve (ribs obscure).
5 *b.* Profile anterior view of a left valve.
5 *c.* Internal impression of a right valve showing the deep byssal sinus at (s).

Fig. 6. *a, b.* . . . . Eumicrotis Hawni, var. ovata. 55

6 *a.* Cast of the exterior surface of a left valve, showing the very short hinge line, and distinct costæ of this variety.
6 *b.* Anterior profile view of same.

Fig. 7. *a, b, c.* . . . . . Myalina permiana. 52

7 *a.* Internal cast of a left valve, usual form. The impression of the hinge area shown in outline in this figure, is added from another specimen.
7 *b.* Anterior view of same.
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Fig. 8. *a, b, c, d.* . . . . Myalina aviculoides. 51

8 *a.* Cast of the exterior of a left valve, adult size.
8 *b.* Anterior view of same.
8 *c.* Cast of exterior of a young specimen.
8 *d.* Anterior view of same.

Fig. 9. . . . Aviculopecten McCoyi, (ext. cast left valve). 50

Fig. 10. . . . Aviculopecten ——— ? (cast left valve). 50

Fig. 11 *a, b.* . . . . Schizodus ovatus. 59

11 *a.* Cast, left valve, side view.
11 *b.* Dorsal view of same.

Fig. 12. *a, b.* . . . . . Bakevellia parva. 57

12 *a.* Cast of left valve, side view, natural size.
12 *b.* Cast of another specimen enlarged.

Fig. 13. *a, b.* . . . . . Pleurophorus Calhouni. 62

13 *a.* Internal cast, side view, showing a cast of the anterior muscular impression, with a furrow behind it, left by an internal ridge.
13 *b.* Dorsal view of the same, being a cast of the interior of the two valves as seen partly opened.

Fig. 14. *a, b.* . . . . . Nautilus eccentricus. 65

14 *a.* Side view of an internal cast, showing the septate and non-septate portions
14 *b.* Dorsal view of same.

EXPLANATIONS OF PLATE II.

PAGE

Fig. 1. *a, b, c.* Chænomya leavenworthensis. 43

1 *a.* Side view, with portions of the shell removed, so as to show the muscular scars, and faintly sinuous pallial impression.
1 *b.* Dorsal view of an internal cast, showing the wide posterior gap.

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2 *b.* Dorsal view of same, showing a distinct depression along the hinge left by an internal thickening of the cardinal margin.

Fig. 3. Pleurophorus? subcuneata. 61

Fig. 4. *a, b.* Yoldia subscitula. 60

4 *a.* Side view of a cast, left valve.
4 *b.* Dorsal view of same.

Fig. 5. *a, b, c.* Eumicrotis Hawni. 54

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5 *b.* Profile anterior view of a left valve.
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Fig. 7. *a, b, c.* Myalina permiana. 52

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7 *c.* Cast of a broader variety of same species not showing the cardinal area.

Fig. 8. *a, b, c, d.* Myalina aviculoides. 51

8 *a.* Cast of the exterior of a left valve, adult size.
8 *b.* Anterior view of same.
8 *c.* Cast of exterior of a young specimen.
8 *d.* Anterior view of same.

Fig. 9. Aviculopecten McCoyi, (ext. cast left valve). 50

Fig. 10. Aviculopecten ——— ? (cast left valve). 50

Fig. 11 *a, b.* Schizodus ovatus. 59

11 *a.* Cast, left valve, side view.
11 *b.* Dorsal view of same.

Fig. 12. *a, b.* Bakevellia parva. 57

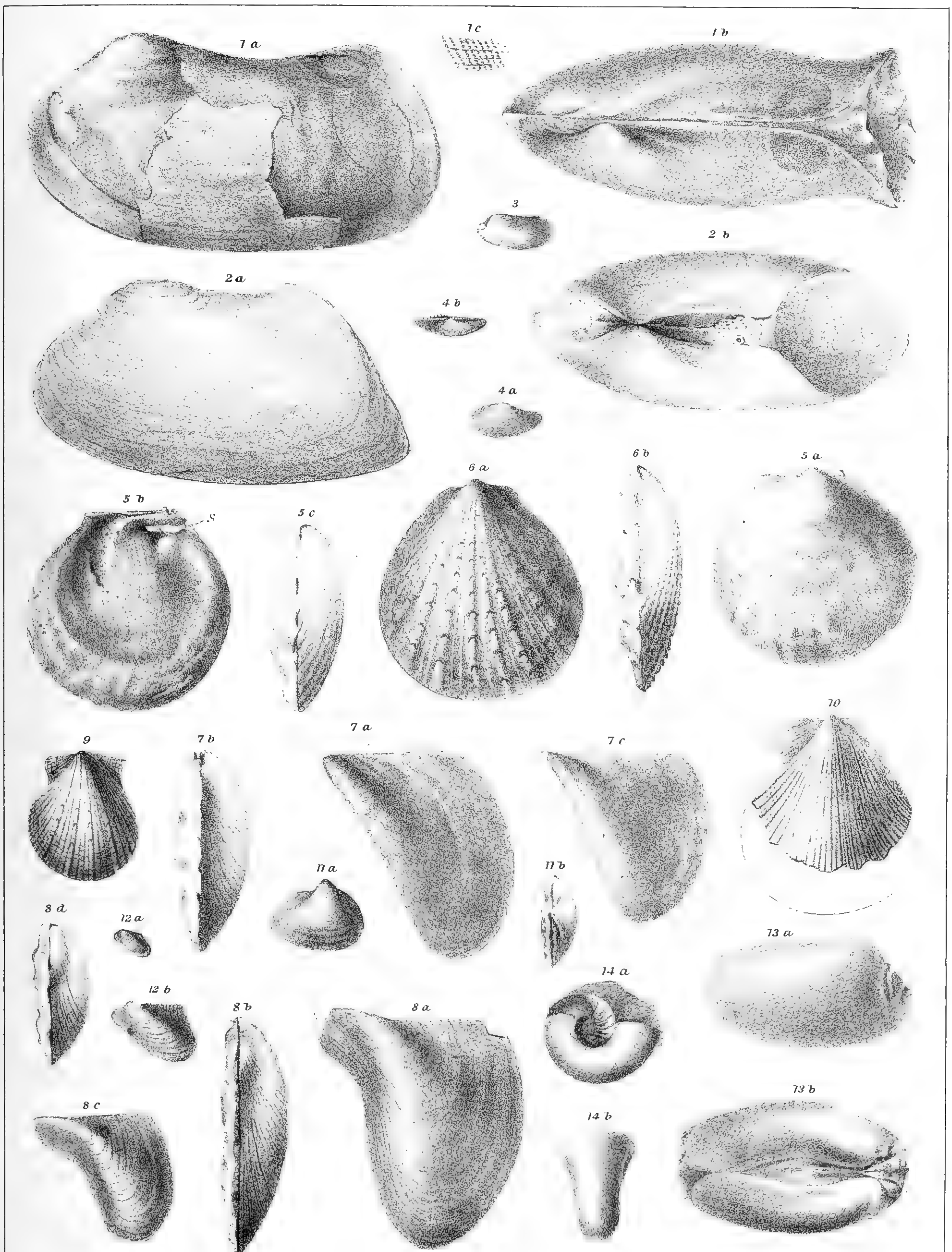
12 *a.* Cast of left valve, side view, natural size.
12 *b.* Cast of another specimen enlarged.

Fig. 13. *a, b.* Pleurophorus Calhouni. 62

13 *a.* Internal cast, side view, showing a cast of the anterior muscular impression, with a furrow behind it, left by an internal ridge.
13 *b.* Dorsal view of the same, being a cast of the interior of the two valves as seen partly opened.

Fig. 14. *a, b.* Nautilus eccentricus. 65

14 *a.* Side view of an internal cast, showing the septate and non-septate portions
14 *b.* Dorsal view of same.



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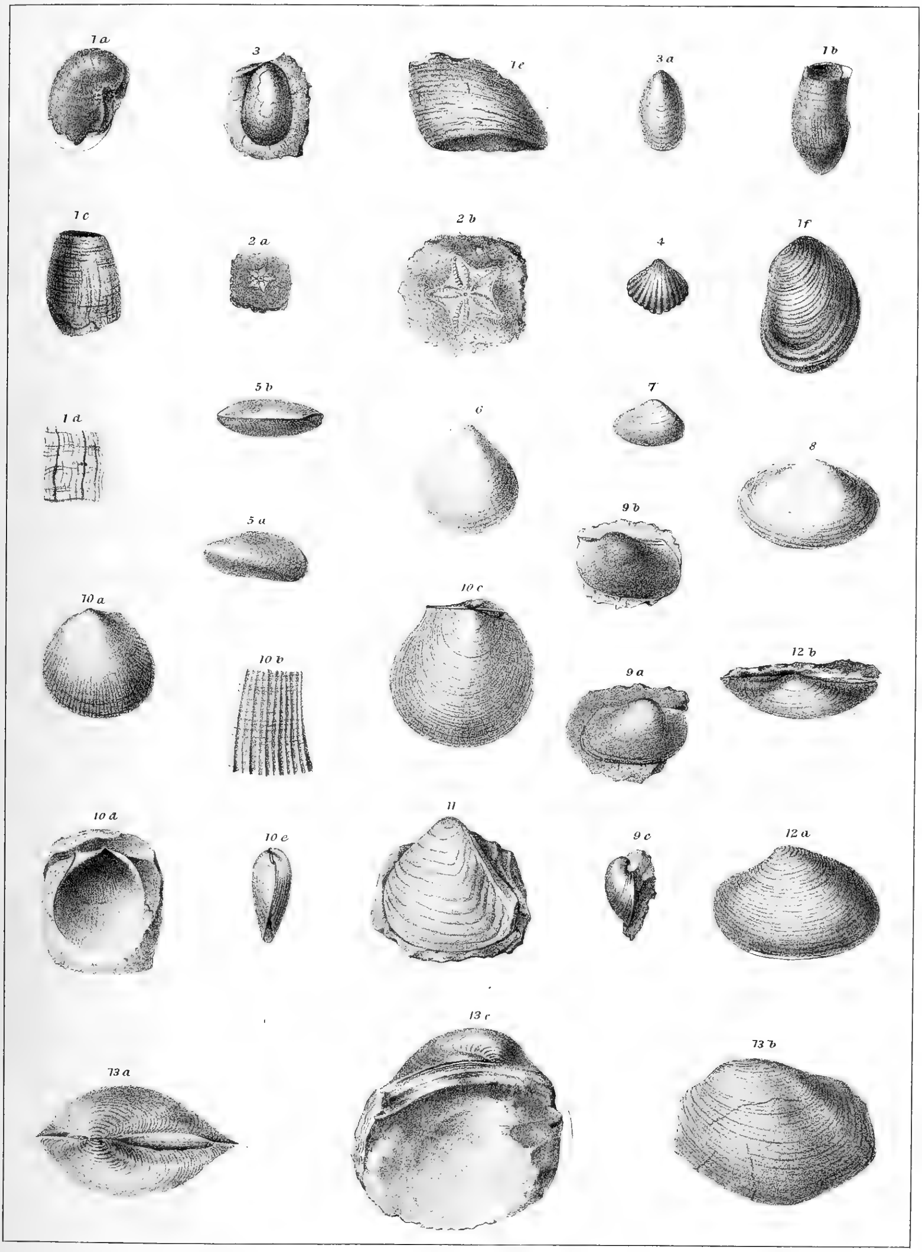
Palæontology of the Upper Missouri.

REPTILIAN AGE. JURASSIC PERIOD.

PL. III.



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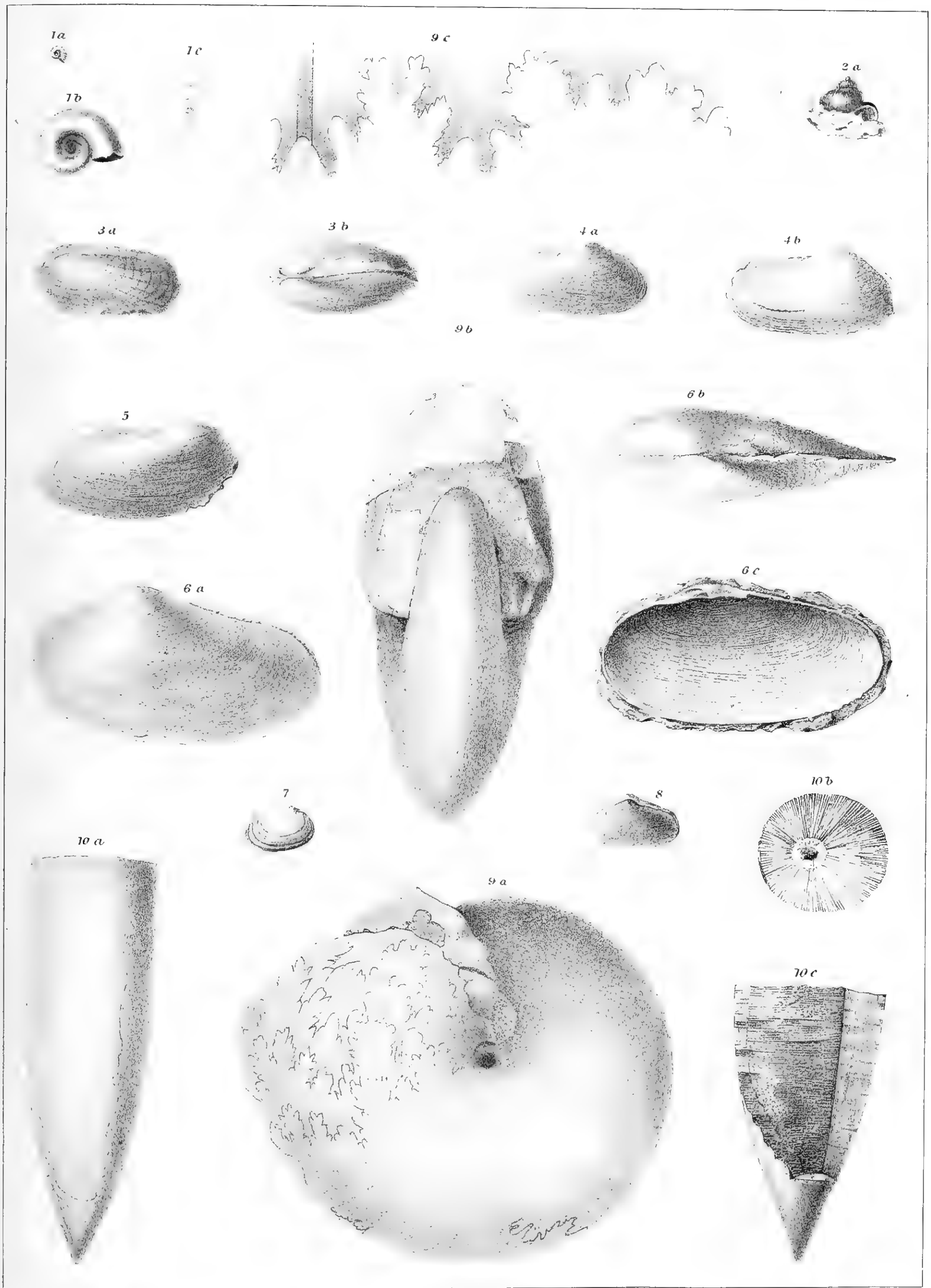
Palæontology of the Upper Missouri.

REPTILIAN AGE, JURASSIC PERIOD. PL. IV.



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3 *b.* Opposite side same.

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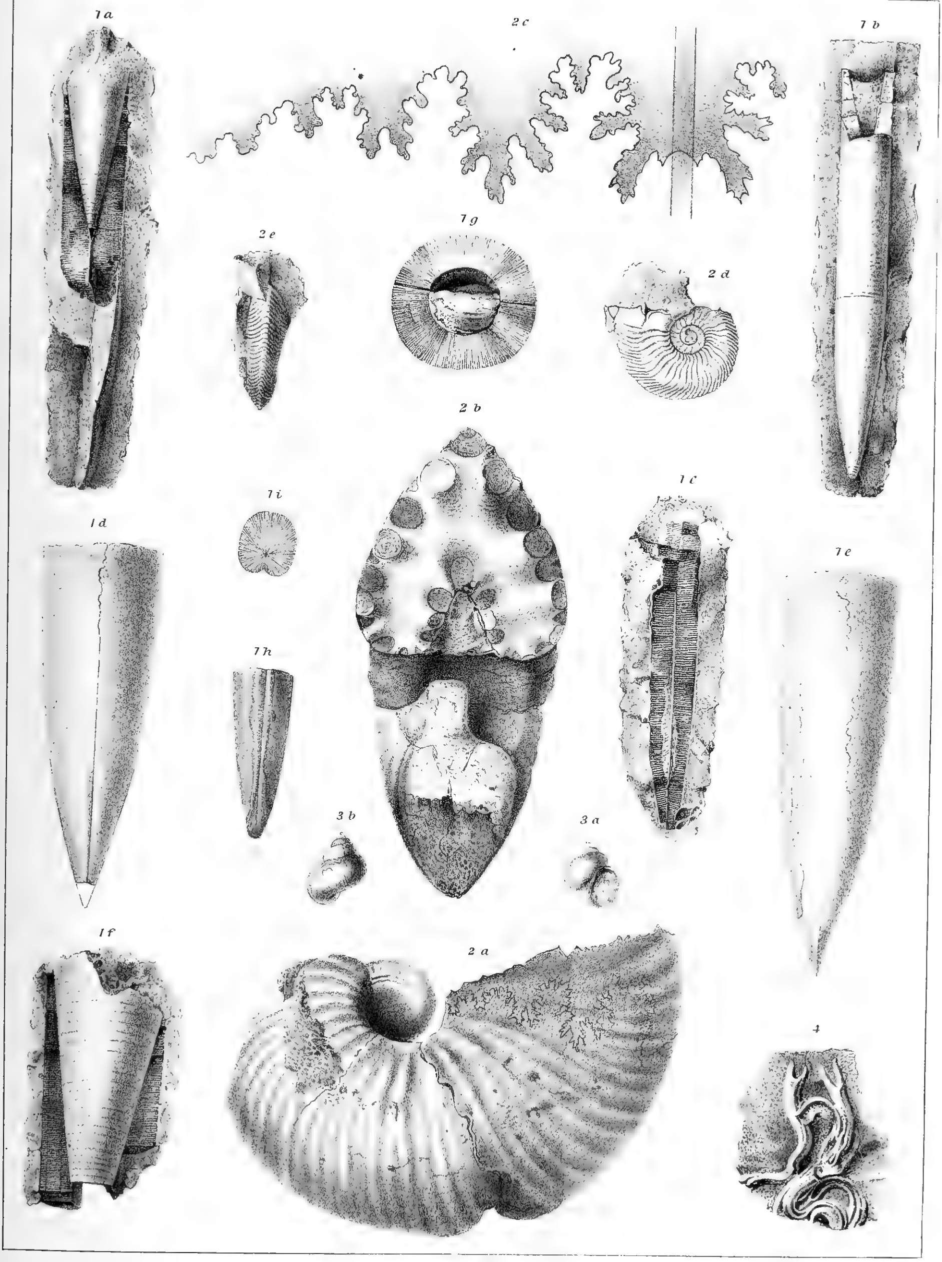

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SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.
192

CRETACEOUS REPTILES

OF THE

UNITED STATES.

BY

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[ACCEPTED FOR PUBLICATION DECEMBER, 1864.]

COMMISSION

TO WHICH THIS PAPER HAS BEEN REFERRED.

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JOSEPH HENRY,
Secretary S. I.

COLLINS, PRINTER,
PHILADELPHIA.

PREFACE.

The following Memoir was commenced seven years ago, and, although various circumstances have interfered with its completion until now, the delay has not been unattended with some advantages. During the lapse of time nearly as much new material has been discovered as was originally at the command of the author, and thus our acquaintance has been greatly extended with the subjects of the memoir. In consequence the latter has been repeatedly altered, and portions have been intercalated, which may serve to explain any apparent want of continuity in the work.

The author takes the opportunity of acknowledging his obligations to Prof. George H. Cook, of Rutgers College, New Brunswick, New Jersey, who has given constant and important aid in procuring specimens for examination during his geological explorations of the State. Acknowledgments are also due to W. Parker Foulke, of Philadelphia, through whose especial exertions we are indebted for the discovery of the huge Reptile, *Hadrosaurus*, which forms one of the most interesting and important subjects of description in the succeeding pages. Valuable assistance has also been rendered by others in obtaining specimens for investigation, but more especially by Dr. J. H. Slack, of Philadelphia. The basis of the work has been mainly founded on the rich collection of the Academy of Natural Sciences of Philadelphia.

CONTENTS.

MEMOIR

ON THE

EXTINCT REPTILES OF THE CRETACEOUS FORMATIONS OF THE UNITED STATES.

INTRODUCTION.

THE present memoir consists of descriptions of remains of Reptiles discovered in the Cretaceous Formations of the United States. It was the author's intention to include an account of the fossil Fishes, of which he had the opportunity of examining numerous specimens, so as to form a monograph of the extinct Vertebrata of the Cretaceous period. These specimens are, however, in so many instances mingled with others derived from Tertiary deposits that he has been led to defer an account of them until he has the opportunity of ascertaining and separating those which belong to the different formations. Other Vertebrata, Bird or Mammal, have not been detected in the Cretaceous deposits of any part of America.[1]

---

[1] I formerly attributed two species of Cetaceans to the Green-sand of the Cretaceous era of New Jersey, which I now believe to be erroneous, and regret the more as I have been quoted in the excellent works of Lyell (Princip. Geol. 9th ed. 145; Man. Elem. Geol. 5th ed. 254) and Dana (Man. Geol. 473, 478) in proof of the existence of such animals during the Cretaceous epoch.

Dr. Harlan described a vertebra (Journ. Acad. Nat. Sci. Phila. VI, 232, Plate xiv, Fig. 1; Med. and Phys. Researches, 282, Fig. 1), from Mullica Hill, N. J., which he considered to belong to a species of *Plesiosaurus*. Having accidentally noticed the specimen in the museum of the Academy, I recognized its cetacean character and referred it to a species with the name of *Priscodelphinus Harlani* (Proc. Acad. Nat. Sci. V, 327). As the formation at Mullica Hill belongs to the Cretaceous epoch, it thus appeared as if evidence was obtained proving the existence of a Cetacean at that age. Several other vertebræ, from the Marl of New Jersey, were at the same time referred to *Priscodelphinus grandaevus* (Ibidem). The latter specimens have since been ascertained to have been derived from a Miocene Tertiary deposit of Shiloh, Cumberland County.

I have since had the opportunity of examining many Cetacean remains from the Miocene deposits of New Jersey, and have been led to the conclusion that the vertebra of *Priscodelphinus Harlani* is a Miocene fossil which had become an accidental occupant of the Green-sand in which it was found.

Not only have Miocene fossils occasionally found their way into the Green-sand of New Jersey, but also the remains of more recent animals. The museum of the Academy contains remains of Mastodon, Beaver, Reindeer, Deer, and Muskrat, from the Green-sand of Burlington and Camden Counties.

The tooth of a Seal, reputed to have been found in the Green-sand near Burlington, New Jersey, Most of the fossil remains which form the subject of the memoir were obtained in New Jersey, and are contained in the museum of the Academy of Natural Sciences of Philadelphia. Very many of them were found in the Green-sand, which, under the name of Marl, is largely excavated for agricultural purposes; others were obtained from limestone. Many specimens have been derived from Maryland, Delaware, North Carolina, Georgia, Alabama, Mississippi, and Nebraska.

The Cretaceous formations compose a large tract extending through the States of New Jersey, Maryland, and Delaware. They also appear in isolated patches in North and South Carolina, and Georgia. More extensively developed in the western portion of the latter State, they curve in a wide crescentoid tract through Alabama, Mississippi, and Tennessee to the mouth of the Ohio River. Thence passing in a narrow band through Arkansas, they afterwards expand to an enormous extent and occupy a great portion of the region between the Mississippi River and the Rocky Mountains, reaching north into the British possessions, and south into Mexico.

When we consider the great development of the Cretaceous formations in the western and southern portions of the United States in comparison with those on the eastern border, from which nearly all our fossils have been obtained, we may anticipate many additions. These will not only increase the number of species and genera, but will serve to clear up many of the obscurities concerning those already in our possession.

According to Messrs. Meek and Hayden,[1] the Cretaceous formations in the region of the Upper Missouri, in section, present the following constitution:—

EARLIER CRETACEOUS—

No. 1. Yellowish, reddish, and whitish sandstones and clays, with lignite and fossil angiospermous leaves, 400 feet in thickness. Located near Dakota, and reaching southward into northeastern Kansas.

No. 2. Gray laminated clays, with some limestone, 800 feet in thickness. Located near Fort Benton, on the Upper Missouri, also below the Great Bend. Characteristic fossils of this division are *Inoceramus problematicus, I. tenuirostris, I. fragilis, Ostrea congesta, Venilia Mortoni, Pholadomya papyracea, Ammonites Mullani, A. vespertinus, Scaphites Warreni*, &c.

No. 3. Grayish calcareous marl, 200 feet in thickness. Location: Bluffs on the Missouri, below the Great Bend. Characteristic fossils consist of *Inoceramus problematicus, I. pseudomytiloides, I. aviculoides, Ostrea congesta*, &c.

LATER CRETACEOUS—

No. 4. Plastic clays, 700 feet in thickness: the middle portion barren of fossils. Located on the Missouri near Great Bend, about Fort Pierre, extending to the Bad Lands, on Sage Creek, Cheyenne River, and White River above the Bad Lands. Characteristic fossils are *Nautilus Dekayi, Ammonites placenta, A. complexus, Baculites ovatus, B. com-*

---

and referred to *Stenorhynchus vetus* (Proc. Acad. Nat. Sci. VI, 377), I also believe to be a Miocene fossil.

Dr. Harlan described the fragment of the femur of a Snipe (*Scolopax*), from the Marl of New Jersey (Med. and Phys. Res., 282), which has been accepted by authors as an ornithic fossil of the Cretaceous period. The specimen, preserved in the museum of the Academy, is of recent origin.

[1] Dana, Manual of Geology, 1863, 469; Proc. Acad. Nat. Sci. 1861, 419.

pressus, Scaphites nodosus, Helicoceras Mortoni, H. tortum, H. umbilicatum, Ptychoceras Mortoni, Fusus vinculum, Anisomyon borealis, Amauropsis paludiniformis, Dentalium gracile, Crassatella Evansi, Cucullæa Nebrascensis, Inoceramus sublævus, I. tenuilineatus, I. Nebrascensis, I. Vanuxemi, bones of *Mosasaurus*, &c.

No. 5. Gray ferruginous and yellowish sandstones and arenaceous clays, 500 feet in thickness. Location: Fox Hills near Moreau River, above Fort Pierre near Long Lake, and along the base of Big Horn Mountains. Characteristic fossils are *Belemnitella bulbosa, Nautilus Dekayi, Ammonites placenta, A. lobatus, Scaphites Conradi, S. Nicolleti, Baculites grandis, Busycon Bairdii, Fusus Culbertsoni,* bones of *Mosasaurus*, &c.

A section of the New Jersey Cretaceous deposits, according to Messrs. Meek and Hayden,[1] as compiled from the observations of Prof. Geo. H. Cook, exhibits the following structure:—

EARLIER CRETACEOUS—

No. 1. Dark blue, ash colored and whitish clays and micaceous sand, with thin seams of *lignite*. Great quantities of sulphuret of iron. Fossil wood in some of the layers in large quantities, and angiospermous leaves. 130 feet or more in thickness.

LATER CRETACEOUS—

No. 4. Dark clays, with occasional streaks and spots of Green-sand, containing *Ammonites Delawarensis, A. placenta, Baculites ovatus,* etc. 130 feet in thickness.

First or lower bed of Green-sand, containing *Nautilus Dekayi, Baculites ovatus, Belemnitella mucronata, Terebratula Sayi, Ostrea larva, Exogyra costata, Gryphæa vesicularis,* etc. 50 feet in thickness.

Quartzose sand, highly ferruginous; argillaceous in its upper part, containing *Belemnitella mucronata, Ostrea larva, Exogyra costata, Neithea Mortoni,* etc. From 65 to 70 feet in thickness.

No. 5. Second bed of Green-sand. This includes the yellow limestone of Timber Creek, containing *Montivaltia Atlantica, Nucleolites crucifer, Ananchytes cinctus,* etc. Also a bed of nearly unchanged shells, among which are *Terebratula Harlani, Gryphæa lateralis, G. convexa,* etc. Lastly, Green-sand, etc., containing *Scaphites Conradi, Baculites ovatus, Ammonites placenta, Cucullæa vulgaris,* etc. From 45 to 50 feet in thickness.

TERTIARY—

Quartzose sand resembling ordinary beach sand, and destitute of fossils. From 45 to 50 feet in thickness.

Third, or upper bed of Green-sand. 60 feet in thickness.

In Alabama, according to Prof. Winchell, as communicated by Messrs. Meek and Hayden,[2] the Cretaceous formations are as follows:—

EARLIER CRETACEOUS—

No. 1. Dark blue and mottled shales or clay, with vegetable remains. 300 feet or more in thickness.

LATER CRETACEOUS—

No. 4. Grayish and yellowish sand, with fossil wood and *Teredo tibialis;* 15 feet.

Gray sand with *Ammonites placenta, A. Delawarensis, Gryphæa vesicularis, Exogyra costata, Inoceramus biformis, Pecten quinquecostatus,* etc.; 6 feet.

Soft white limestone ("Rotten limestone"), with *Nautilus Dekayi, Ammonites Delawarensis, Baculites ovatus,* etc.; 150 feet or more.

Loose white sand, with *Ostrea larva, Pecten quinquecostatus, Gryphæa vomer,* etc.; 45 feet.

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[1] Proc. Acad. Nat. Sci. 1857, 127; 1861, 426.

[2] Ibidem 1857, 126.

No. 5. Soft white limestone, with *Nautilus Dekayi, Baculites ovatus, Scaphites Conradi, Gryphæa vesicularis, Exogyra costata,* etc.; 6 feet.
Dark limestone, with obscure casts of shells; 4 feet.

In Texas the formations consist mainly of compact limestone. Dr. Shumard[1] gives the following section:—

EARLIER CRETACEOUS—

No. 1. Marly clay, with *Ammonites Swallovii, A. Meekianus, Ancyloceras annulatus, Scaphites vermiculus, Baculites gracilis, Inoceramus capulus,* etc.; 150 feet in thickness.
Arenaceous beds, with *Ostrea bellarugosa,* remains of fishes, etc.; 80 feet.
No. 2. Caprotina limestone, with *Orbitolina Texana,* etc.; 55 feet.
Blue marl, with *Inoceramus problematicus,* etc.; 50 feet.
No. 3. Washita limestone, with *Gryphæa Pitcheri, Inoceramus problematicus, Hamites Fremonti,* etc.; 100 to 120 feet.
Indurated blue marl, with *Exogyra arietina,* etc.; 60 feet.

LATER CRETACEOUS—

No. 4. Austin limestone, with *Gryphæa vesicularis, Exogyra costata, Nautilus Dekayi, Baculites anceps,* remains of fishes, etc.; 100 to 120 feet.
Comanche Peak Group, with *Exogyra Texana, Gryphæa Pitcheri, Cardium multistriatum, Ammonites Pedernalis, Heteraster Texanus, Diadema Texana,* etc.; 300 to 400 feet.
Caprina limestone, with undetermined species of shells; 60 feet.

Other localities[2] of Cretaceous formations of the different subdivisions are as follows:—

No. 1. At different points in New Mexico. (Newberry.)
No. 2. On the north branch of the Saskatchewan, west of Fort à la Corne, lat. 54° N., in New Mexico. (Meek.)
No. 3. Over the region from Kansas through Arkansas to Texas; Pyramid Mountain, N. Mexico.
No. 4. In British America, on the Saskatchewan and Assiniboine; on Vancouver Island; Sucia Islands, in the Gulf of Georgia.
No. 5. At Deer Creek, on the North Platte, and not identified south of this. (Meek and Hayden.)

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[1] Transac. Acad. of Sciences of St. Louis, I, 583.
[2] Dana, Manual of Geology, 470.

SAURIA.

THORACOSAURUS.

Thoracosaurus neocesariensis.

New Jersey Gavial, De Kay, Ann. Lyc. Nat. Hist. N. Y. III, 1833, 156, pl. iii, figs. 7–10.
Gavialis neocesariensis, De Kay, Zool. New York, 1842, part III, 28, pl. 22, fig. 59.
Crocodilus s. Gavialis clavirostris, Morton, Proc. Acad. Nat. Sci. Phila. III, 1844, 82.—Giebel, Fauna d. Vorwelt, 1847, 122.
Crocodilus basifissus, Owen, Jour. Geol. Soc. Lond. V, 1849, 381, pl. x, figs. 1, 2; Palæontology, 1860, 277.—Pictet, Traité de Palæont. I, 1853, 482.
Sphenosaurus, Agassiz, Proc. Acad. Nat. Sci. Phila. IV, 1849, 169.
Thoracosaurus grandis, Leidy, Proc. Acad. Nat. Sci. Phila. VI, 1852, 35.

The most characteristic of the Crocodilian remains, obtained from the strata of the Cretaceous period in the United States, consists of a nearly entire skull, which was discovered in limestone, overlying the ferruginous Marl, on the farm of Gen. William Irick, near Vincenttown, Burlington County, N. J. The specimen was presented by that gentleman, and Mr. Wm. Whitman, of this city, to the Academy of Natural Sciences, in the cabinet of which it is now contained. This finely preserved fossil consists of the skull, without the lower jaw. It has lost the anterior extremity of the muzzle, estimated to have been equal to half its original length. The teeth are also broken away, but sockets with the remains of fangs for fourteen of the back teeth exist on each side of the fossil. The zygomatic arches, as formed by the squamosals, are broken away, as is also the case with the articular ends of the tympanics and the lower or outer conjoined extremities of the ecto- and entopterygoids.

The matrix, in which the fossil was imbedded, for the most part has been chiselled away. Portions still adherent and occupying one orbit and palatine orifice, besides the interior of the cranium and nasal passages, consist of a moderately hard, gray arenaceous limestone. The bones of the fossil are brown and friable.

In general shape and construction the fossil skull exhibits more resemblance to that of the existing Gavial of the Ganges (*Gavialis Gangeticus*) than of any other of the living crocodilian Reptiles, though from the non-eversion of the orbits and the more gradual prolongation of the muzzle it also presents a relationship to the genus *Mecistops*, of Western Africa. Of all known forms, however, it bears most resemblance to the skull of the extinct *Gavialis macrorhynchus*, of the Cretaceous formations of Europe.

In consequence of the anterior extremity of the muzzle being lost in the New Jersey specimen, we have no positive means of ascertaining the length of the skull. Supposing it, however, to have held the same relation of length to breadth as in the recent Gavial, in its perfect condition it would have measured about three and three-quarter feet in length and one and a-half feet in breadth. The relation of length to breadth in the *Gavialis macrorhynchus*, with which the New Jersey species appears to be most closely allied, is rather less, and would have made our fossil head about three and a-half feet in length. If we allow as many vertebræ to the New Jersey Gavial as are possessed by the existing species, or the same proportionate length of body to the head, the former animal in its entire condition would measure twenty feet in length.

The upper view of the fossil skull, represented in Fig. 1, Plate I, bears a strong resemblance to that of the living Gavial, except that the boundaries of the orbits are not conspicuously everted as in the latter, and the muzzle is not so abruptly narrowed forward. In the characters just mentioned the fossil appears intermediate to the Gavial and *Mecistops*, and resembles the Teleosauri of the Liassic formations of Europe, but most closely the Cretaceous *Gavialis macrorhynchus.* The posterior and lateral outlines of the cranium are the same in both the New Jersey and living Gavials, as is also the form of the large temporal foramina. The space separating the latter in our fossil, formed by the symmetrical parietal, is both relatively and absolutely narrower than in the living Gavial. The forehead, as formed by the frontal and pre-frontals, has almost the same proportionate breadth as in the latter, but is only slightly concave in consequence of the non-eversion of the orbital borders. The frontal in the fossil, as is also the case in the *Gavialis macrorhynchus*, is prolonged considerably more posteriorly to join the parietal than in the recent Gavial or *Mecistops.* The orifices of the orbits, when perfect, appear to have had nearly the same proportionate size and form as in the living Gavial, but their borders in no position are everted, not even so much as in *Mecistops*, or the Alligator, *A. Mississipiensis.*

The post-frontals, separating the orbits from the temporal foramina, are proportionately narrower than in the recent Gavial; while the post-orbital arches, formed through conjunction of the post-frontals with the malars, are broader.

As in the extinct *Gavialis macrorhynchus*, the face in advance of the forehead and orbits in the New Jersey fossil slopes with a gentle curve forward to the broken end of the muzzle.

The malar and lachrymal are more prolonged upon the face or muzzle than in the recent Gavial. Thus in the latter, the anterior border of the malar reaches as far forward as the position of the fourth tooth, counting from behind, and the lachrymal advances as far as the sixth tooth. In the fossil the malar extends as far forward as the seventh tooth, and the lachrymal reaches beyond the position of the ninth tooth.

The posterior extremities of the nasals are angular, and extend back on a line with the anterior orbital margins. They widen forward to the anterior ends of the pre-frontals, then very gradually narrow forward a short distance beyond the lachrymals, and finally narrow abruptly into a pair of linear prolongations extending to the broken end of the fossil. A similar condition of the nasal bones is observed to exist in the *Gavialis macrorhynchus.*

The surface of the cranium, as formed by the parietal, mastoids, frontals, pre- and post-frontals, is less foveated than in the full-grown Gavial of the Ganges; and the surface of the muzzle is likewise rather less roughened, though perforated by as many vasculo-neural foramina.

On both sides of the face, in the fossil, there is a large hole, situated between the lachrymals and pre-frontals, a short distance in advance of the inner part of the orbits, which, though perhaps accidental, reminds one of the unossified spaces noticed in a somewhat similar position in the Deer among Mammals, and corresponding with the orifices represented as existing in the *Teleosaurus* or *Pelagosaurus typus*,[1] between the lachrymals and nasals.

The lateral view of the fossil skull, represented in Fig. 2, Plate I, is nearly repeated by that of the corresponding portion of the skull of the recent Gavial, except that the face in the former presents a more gradual slope from the position of the orbit.

The occipital view of the fossil also bears a near resemblance to that of the recent Gavial; its upper outline, however, is more nearly horizontal, and is not prominent at the middle. The supra-occipital is much broader in relation with its height than in the recent Gavial, or the Alligator. Its upper extremity forms a square plate, with everted edges, over an inch in breadth, articulating by transverse suture on the top of the cranium with the parietal.

The exoccipitals, the occipital condyle, and the occipital foramen present nothing peculiar. The latter is an inch and a half in breadth and ten lines in height.

The inferior view of the fossil skull, represented in Fig. 1, Plate II, though presenting the same general outline of form and construction as in the recent Gavial, nevertheless exhibits a number of important peculiarities. The palatine foramina, as in *Gavialis macrorhynchus*, are much larger than in the recent Gavial. They are ovoidal, with their narrow extremity forward and their inner sides nearly parallel. They extend from the ento-pterygoids as far forward as the position of the seventh tooth, counting from behind. The part of the skull corresponding with the position of the foramina and the intervening palatines rises even more than in *Mecistops*. The anterior extremities of the palatines reach as far forward as the position of the ninth tooth from behind. In advance of the palatines the surface of the muzzle is flat.

Neither the palatines nor the ento-pterygoids present capsular osseous dilatations, such as exist in the recent Gavial.

The posterior nares are large, and, as in the Alligator and the extinct *Gavialis macrorhynchus*, are divided by an osseous septum of the ento-pterygoids. The lower border of this septum forms a stout ridge expanding behind upon the basisphenoidal. The latter includes a large, transversely oval pit, communicating with a canal piercing the bone as in other Crocodilians.

The under surface of the tympanics, as observed in this view of the skull, exhibits a deep and wide gutter or concave fossa, of which only a superficial trace is present in the recent Gavial.

The remaining portions of the maxillæ in the fossil, on each side, contain the sockets and portions of the fangs of fourteen teeth, occupying a space sixteen and a half inches in length.

Compared with the skull of *Gavialis macrorhynchus*, as represented by the figures

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[1] See Fig. 7, Plate XXV, of the Atlas to Pictet's Traité de Paléontologie, 2d ed.

of De Blainville[1] and Gervais,[2] that of the extinct Gavial of New Jersey was more than one-third larger. These two Cretaceous Crocodilians present characters in common, so peculiar in comparison with other known forms, recent and extinct, that they may be considered as belonging to a distinct genus, for which the name of *Thoracosaurus* has already been proposed for one of the species, and may equally apply to the other.

Measurements of the Skull of THORACOSAURUS NEOCESARIENSIS.

	Inches.	Lines.
Estimated length of skull from 42 inches to	45	
Breadth at condyles of tympanics or articulation of the lower jaw	17	
Breadth of face at the last teeth	12	
Breadth of face at the fourteenth teeth, counting from behind	3	7
Height of cranium at the occiput	6	3
Breadth of cranium at the posterior border of the orbits crossing the parietal and mastoids	12	6
Distance from summit of the occiput to anterior extremity of the frontal	11	
Length of alveolar border from back end of maxilla to the fourteenth alveolus, or broken end of the fossil	17	
Length of palatines in the median suture	9	6
Breadth of palatines together at the middle	2	9
Length of palatine foramina	8	
Breadth of palatine foramina	3	6
Distance from occipital condyle to broken end of the muzzle, corresponding with the fourteenth tooth, counting from behind	29	
Breadth of muzzle at anterior extremity of the palatine foramina	8	
Breadth of cranium at middle of the temporal foramina	3	
Transverse and antero-posterior diameters of the temporal foramina	4	3
Transverse and antero-posterior diameters of the orbits	3	3
Distance apart of orbits where nearest	4	3
Distance apart of temporal fossæ		6½
Length of frontal	7	
Breadth of frontal between post-frontals	5	6
Length of parietal	4	
Breadth of parietal posteriorly	4	5
Distance between anterior ends of malars	4	10
Breadth of nasals between anterior ends of pre-frontals	3	1
Breadth of nasals between anterior ends of lachrymals	1	9
Diameter of posterior nares	1	8
Thickness of border of septum between the latter		5

A small fragment of the lower jaw of an extinct Gavial from the ferruginous sandstone, of the Cretaceous era, of the Highlands of Navesink, New Jersey, was described by Dr. J. E. De Kay, in 1833, in the third volume of the Annals of the Lyceum of Natural History of New York, page 158. The fragment, now more mutilated than formerly, I have had the opportunity of inspecting, through the kindness of Prof. E. Emmons, of Albany. The specimen is about six inches in

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[1] Osteographie; Reptiles, Plate 6, Crocodilus macrorhynchus.

[2] Zoologie et Paléontologie Francaises, Plate 59, fig. 18.

length and corresponds with that part of the jaw just in advance of the divergence of the rami, and consists of portions of both dentals and splenials. The right dental contains remains of four alveoli with portions of their teeth, of which one incloses the entire crown of a successional tooth.

This fossil fragment of the lower jaw I suspect to belong to the same species as the Vincenttown skull, but to a smaller or younger individual. The symphysis of the splenials, preserved at the posterior part, in the perfect condition, is estimated to have been about seven inches in length. The breadth of the jaw at the back extremity of the symphysis of the splenials is estimated to have been about four and a quarter inches; and at the fore extremity two and three-quarter inches. The oral surface of the splenials and dentals presents about the same degree of convexity as in the recent Gavial.

The cabinet of the Academy contains a fragment of the left upper maxilla, apparently belonging to the same Gavial as the fossil skull just described, which is of especial interest from its retaining several entire and well-preserved teeth. The specimen, together with some small fragments of the jaw and teeth of the same individual, were obtained by Dr. J. L. Burtt, from the Cretaceous limestone, near Blackwoodtown, Camden County, N. J. The fragment to which we especially refer, represented in Fig. 2, Plate II, is about eight inches long, and corresponds with that portion of the left maxilla in the fossil skull which contains the back six teeth with the exception of the one or two last ones. It has a portion of the malar attached, and belonged to a rather larger individual than the Vincenttown skull, for it contains one tooth less in the space occupied by seven in the latter.

The crowns of the teeth protruding from the specimen are curved conical as in the recent Gavial, but are more robust in proportion with their length. The ridges separating their outer and inner surfaces are also less prominent than in the living Gavial. The more anterior of the teeth, towards the base of the crown, internally exhibit a slightly fluted disposition. The enamel, which is jet black, is closely striated longitudinally with fine linear ridges, and also presents a feeble annular disposition towards the summits of the crowns.

The measurements of the teeth, counting them from behind forward, are as follows:—

	Lines.
Length of crown of third tooth	7¾
Diameter of base from without inwardly	5½
Length of crown of fourth tooth	10
Diameter of base from without inwardly	6¼
Diameter of base at the divisional ridges	7½
Length of crown of sixth tooth	13½
Diameter of base from without inwardly	8
Diameter of base at the divisional ridges	9½
Length of sixth tooth to bottom of alveolus	39
Diameter of base of eighth tooth from without inwardly	9½
Diameter of base of eighth tooth at divisional ridges	10

A detached tooth, represented in Fig. 4, Plate I, from the same individual as the fossil fragment of jaw just described, presents the same characters as those contained in the latter.

Two isolated teeth, obtained by Dr. Burtt from the same formation as the preceding specimens, exhibit identical characters with those above described.

The crowns of two additional teeth from the Green-sand, near Blackwoodtown, Camden County, N. J., presented by Dr. Burtt to the Academy, probably belong to the same species as the foregoing. They are narrower in proportion to their length than those in the fragment of jaw, but may have occupied a more anterior position in the series.

The successional tooth, alluded to in the jaw fragment described by Dr. De Kay, resembles the larger of the two just indicated.

The summits unworn of two successional teeth, seen protruding from within the fangs of broken functional teeth, in the Vincenttown skull, in the corrugated appearance of their enamel and in other characters, are identical with those of the teeth described.

The cabinet of the Academy also contains several small fragments of jaws, with entire teeth, from the Cretaceous limestone of Big Timber Creek, Gloucester Co., N. J., presented by Messrs. R. Haines, J. P. Smith, T. McEuen, and S. G. Morton. The teeth, of which the most perfect is represented in Fig. 6, Plate I, correspond in size, form, and proportions, with those contained in the fragment of jaw presented by Dr. Burtt.

Of five specimens, consisting of crowns of teeth, and probably referable to the same species as the preceding, from the Green-sand of Burlington County, N. J., presented to the Academy by Lewis T. Germain, the more perfect are represented in Figs. 3 and 5, Plate I. One of these corresponds in its proportions with the teeth in Dr. Burtt's fossil, and in the fragments from Big Timber Creek. The other is much longer in relation with its diameter, and probably belonged to the anterior part of the jaw.

Accompanying the teeth, presented by Mr. Germain, there is a mutilated specimen of a posterior caudal vertebra, the body of which is a little over three inches in length, and is eleven lines in transverse diameter at its middle.

Of other fossils referable to the extinct Gavial of New Jersey, contained in the cabinet of the Academy, there is a coherent mass of much mutilated bone fragments, obtained from the Green-sand, and presented by Daniel Brinton. The fragments are exceedingly friable, and are cemented together by a portion of the Green-sand matrix. One of them consists of a portion of the left maxilla, and possesses the same size and form as the corresponding portion of the jaw of the Vincenttown skull just in advance of the palatine foramen. The outer part of the alveoli is destroyed and all traces of the teeth have disappeared. The best preserved of the fragments consists of the greater part of a fourth or fifth cervical vertebra, represented in Figs. 5, 6, Plate III. It is identical in character with the vertebra from the New Jersey Green-sand, described and figured by Prof. Owen, as indicating a species of Crocodile or Alligator, for which he proposed the name of *Crocodilus basifissus*.[1] The specific term was given in consequence of the cleft condition of the process or hypapophysis beneath the fore part of the vertebral body. The cervical

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[1] Journ. Geol. Soc. London, V, 381, pl. x, figs. 1, 2.

vertebræ of the *Gavialis*, or, as we may call it, *Thoracosaurus macrorhynchus*, appear also to have possessed the same discriminating character, as represented by Fig. 22, Plate 59, of the Atlas to Gervais' Paléontologie.

Other fragments adherent to the mass consist of a portion of another cervical vertebra, a much mutilated posterior caudal vertebra corresponding in its proportions with the one above indicated, an uncharacteristic piece of an ulna, and a mutilated upper extremity of a humerus.

A dermal plate and part of another, presented to the Academy by Dr. S. G. Morton, and obtained from the Green-sand of Mount Holly, Burlington Co., N. J., is probably referable to the same species. The specimens are black, dense, and heavy from the infiltration of ferruginous matters. They are deeply foveated on their free surface, and are devoid of any trace of a carina. The more perfect specimen, represented in Fig. 3, Plate II, is nearly oblong square, and measures three and a half by three inches in breadth, and is half an inch in thickness along the middle. Upon these dermal plates I formerly proposed the name of *Thoracosaurus grandis.*[1]

Since writing the preceding, I have received for examination a collection of crocodilian fossils from Prof. Cook, of Rutger's College, New Brunswick, N. J., which are referable to the *Thoracosaurus Neocesariensis.* The fossils were obtained from the Green-sand of Monmouth County, N. J., and are black, dense, and in a good state of preservation. They consist of ten vertebræ, and a fragment of a dermal plate resembling those above described, all apparently from the same individual, which had reached maturity.

Of the vertebræ, one, represented in Fig. 7, Plate III, appears to be the sixth cervical, and has lost its spinous and articular processes. It agrees in size and details with the specimen of a fourth or fifth cervical vertebra above described, and with that described by Prof. Owen as characteristic of the *Crocodilus basifissus*, excepting that its hypapophysis exhibits a mere trace of fission; a condition, however, which indicates its more posterior position in the cervical series.

Two other vertebræ, preserved nearly entire, are the first and third dorsal, of which the latter is represented in Fig. 8, Plate III. The former has lost its hypapophysis, but otherwise both specimens resemble in the details of form the corresponding bones of the Mississippi Alligator.

The remaining specimens consist of the series apparently unbroken, from the eighth dorsal to the second lumbar, inclusive. The eighth and ninth dorsals, Fig. 9, Plate III, have lost all the processes from their vertebral arches, and their bodies are coossified by a huge exostosis. The tenth dorsal, Fig. 10, retains its spinous process, and is five and three-quarter inches high posteriorly. The last pair of dorsals and the two lumbars, of which the first is represented in Fig. 11, have lost their vertebral arches. In form and proportions all the specimens agree with the corresponding bones of the Mississippi Alligator.

Measurements of the specimens are as follows:—

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[1] Proc. Acad. Nat. Sci. Phila. VI, 1852, 35.

	Lines.
Length of sixth cervical vertebra at the lower part of the body	28
Breadth of body anteriorly	25
Height of body anteriorly	23
Height of vertebral canal anteriorly	7
Width of vertebral canal anteriorly	11
Length of body of first dorsal laterally	24
Breadth of body of first dorsal anteriorly	26
Height from lower part of body posteriorly to summit of spinous process	68
Height of vertebral canal anteriorly	7
Width of vertebral canal anteriorly	12
Length of body of third dorsal inferiorly	26
Length of body of third dorsal laterally	24
Length of hypapophysis	9
Width of hypapophysis at middle	10
Height from end of hypapophysis to summit of spinous process	88
Height of body anteriorly	25
Width of body anteriorly	27
Height anteriorly from lower edge of body to summit of spinous process	75
Length of spinous process anteriorly from edge of vertebral canal	43
Height of vertebral canal anteriorly	9
Width of vertebral canal anteriorly	11
Length of transverse process above	24
Length of coossified eighth and ninth dorsal bodies laterally	58
Height of body of eighth dorsal anteriorly	27
Width of body of eighth dorsal anteriorly	25
Height of vertebral canal anteriorly	8
Width of vertebral canal anteriorly	7
Length of body of tenth dorsal inferiorly	30
Length of body of tenth dorsal laterally	29
Height of body anteriorly	26
Width of body anteriorly	27
Height of vertebral canal anteriorly	8
Width of vertebral canal anteriorly	7
Height of spinous process anteriorly	34
Width of spinous process at middle	18
Length of body of eleventh dorsal laterally	28
Length of body of twelfth dorsal laterally	30
Length of bodies of first and second lumbars laterally	32
Height of body of first lumbar anteriorly	24
Width of body of first lumbar anteriorly	29

BOTTOSAURUS.

Bottosaurus Harlani.

Extinct species of Crocodile, Harlan, Journ. Acad. Nat. Sci. Phila. IV, 1824, 15, pl. 1.
Crocodilus Harlani, Meyer, Palæologica, 1832, 108.
Crocodilus macrorhynchus, Harlan, Med. and Phys. Researches, 1835, 369; Trans. Geolog. Soc. Penn. I, 1835, 76; Edinb. New Phil. Journ. XVIII, 1835, 28; Jahrb. f. Miner. 1836, 105.—Giebel, Fauna d. Vorwelt, 1847, 122.
Bottosaurus, Agassiz, Proc. Acad. Nat. Sci. Phila. IV, 1849, 169.
Crocodilus basitruncatus, Owen, Jour. Geol. Soc. Lond. V, 1849, 380; Palæontology, 1860, 277.—Pictet, Traité de Paléont. I, 1853, 482.

In the fourth volume of the Journal of the Academy of Natural Sciences, 1824, Dr. Harlan described the fragment of a lower jaw, obtained from the Green Sand, and presented to the Academy by Samuel Wetherill, of Burlington, N. J. The specimen was referred to an extinct species of Crocodile, which, in 1832, was indicated in the Palæologica of Meyer, as *Crocodilus Harlani.* Subsequently, Dr. Harlan, in his Medical and Physical Researches, published in 1835, named the species *Crocodilus macrorhynchus*, by which name it is generally indicated by systematic writers.

The fragment consists of the greater portion of the right dental bone, and is accompanied by a portion of the corresponding angular bone, apparently from the same jaw. The specimens are black and heavy, and like many other of the Greensand fossils are infiltrated with sulphuret of iron, in consequence of the decomposition of which they are in a less well preserved condition than formerly.

The fragment of the dental bone, represented in Figs. 19, 20, Plate IV, is about fifteen inches in length, and in this extent contains the remains of eleven alveoli, which perhaps comprise the whole number except three or four. It corresponds nearly in form and proportions with the homologous portion of the jaw of the Crocodile or Alligator. The posterior portion of the symphysis is preserved; and reaching quite to it, along the inner side of the bone, is the sutural surface of the splenial. The enlargements of the dental bone for the accommodation of the canine and posterior largest teeth occupy nearly the same relative position as in the Crocodile (*C. palustris*), and are separated as in the latter by a cylindroid portion of the jaw, which in the specimen measures two and a half inches in diameter transversely, and about the same extent of depth. The outer surface of the bone is abundantly supplied with unusually large vasculo-neural foramina. The remains of the alveoli, so far as one can judge in their mutilated condition, appear to indicate a succession of teeth related to one another in size nearly as in the series of the Crocodile or Alligator.

The fragment of the angular bone, represented in Fig. 21, Plate IV, is a portion intermediate to the oval angulo-dental foramina and its posterior prolongation. Its outer surface is vertical, and foveated, and its base or under border is convex, and measures two and a quarter inches in thickness.

Of three teeth which accompanied the fragments above described two are much mutilated, one only having an entire crown. One of the mutilated specimens appears to have occupied the third alveolus, back of the canine, and was comparatively small. The other, represented by Fig. 8, Plate 9 of Dr. Harlan's memoir, apparently occupied the eighth or ninth alveolus back of the canine. It possessed a mammiliform crown, from which the enamel is destroyed, and has a gibbous fang. The third specimen is the penultimate or last tooth, represented in Figs. 11, 12, Plate XVIII, and closely resembles the corresponding teeth of living Crocodiles. The fang was gibbous; and the crown is laterally compressed mammiliform, with its outer and inner surfaces separated by a prominent ridge, and its enamel strongly corrugated. The crown is six lines high, eight lines and a half antero-posteriorly, and six lines transversely.

Upon the fossils above described, Prof. Agassiz infers Harlan's Crocodile to belong to a different genus from any previously known, for which he proposes the name of *Bottosaurus.*[1]

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[1] Proc. Acad. Nat. Sci. Phila. IV, 169.

I have not had the opportunity of inspecting other fossil remains which may positively be referred to the *Bottosaurus Harlani.*

Among the fossils from the New Jersey Green Sand, described by Mr. Owen, in the Journal of the Geological Society, Vol. V. p. 380, before mentioned, there was a cervical vertebra of a crocodilian different from that upon which he proposed the name of *Crocodilus basifissus.* This second vertebra, from its having the inferior apophysis of the body, or the hypapophysis, short and flattened, he views as indicating a species, for which he has proposed the name of *Crocodilus basitruncatus.* The vertebra, supposed to characterize the latter, is of a size which relates to that of the individual to which the jaw fragments above described belong, and probably also appertained to Harlan's Crocodile.

Since writing the above there have been presented to the Academy, by Horatio C. Wood, a number of small fragments of the lower jaw of *Bottosaurus Harlani,* from Burlington County, N. J. The specimens, however, present no further characters in relation to the species. Accompanying them there is a tooth, represented in Fig. 14, Plate XVIII, which is a reduced one of the same form as that already described.

I have also recently received for examination, from the Burlington Co. Lyceum of Natural History, several small fragments of a jaw, two teeth, and a large costal rib, probably belonging to the same species.

The fragments of a jaw are uncharacteristic. One of the teeth has a quadrilateral fang two and a half inches in circumference. The crown is quadrate mammiliform, but has lost the greater part of its enamel. The other tooth is represented in Fig. 13, Plate XVIII. It has a compressed cylindrical fang a little less in circumference than the preceding. The crown is compressed mammiliform, strongly rugose, and has its inner and outer faces defined by prominent carina-like ridges. It measures eight and a half lines long, ten lines wide at base, and seven and a half lines from without inwardly.

Undetermined Species of Crocodiles.

Of other remains of Crocodiles, with vertebræ constructed on the same plan as the living representatives of the family, I have seen a number of specimens from the Green-sand of New Jersey apparently indicating several species different from the preceding. Among these is a collection of bones belonging to the same individual, from Timber Creek, Gloucester County, N, J., presented to the Academy by W. P. Foulke. They consist of two cervical, a dorsal, the sacral, and two caudal vertebræ, and portions of both humeri. The vertebræ indicate an adult animal, as the arches are completely united with their respective bodies, and those of the sacrum are firmly coosified. Their comparatively small size renders it improbable that they should belong to either of the species previously indicated.

The bones are black, heavy, and firm, but unfortunately the vertebræ have had most of their processes broken off since their discovery.

The least mutilated of the cervical vertebræ, apparently the sixth, represented in Fig. 12, Plate III, is rather less than two inches in length, independent of the articular convexity of its body. Inferiorly, the latter is divided by a median carina expanding in front into a broad flat space without a distinct hypapophysis, otherwise the specimen presents nothing remarkable by which to characterize it. The other vertebra of the neck, apparently a fourth or fifth, has the inferior carina of the body almost obsolete—commencing in a small tubercle behind, and fading away as it approaches a concavity extending between the parapophyses or inferior transverse processes. The latter are more robust than in the former specimen, and appear to have been conjoined by a ridge-like hypapophysis, though this is too much broken to judge of its true character.

The dorsal vertebra, Fig. 13, Plate III, the fifth of the series, has about the same length as those of the neck, and is nearly as broad anteriorly as it is long. Its hypapophysis is a robust mammillary tubercle, but it is otherwise like the corresponding bone of the common Alligator.

The conjoined bodies of the sacral vertebræ, represented in Fig. 14, Plate III, relate in size with the preceding, and differ in no important point with the homologous parts of the Alligator.

Of the caudal vertebræ, one is the first of the series, distinguished by the double articular convexity of the body, as seen in Fig. 15, Plate III. Unlike that of the Alligator, it is broad and flattened beneath, resembling in this respect more the condition of the bodies of the sacral vertebræ. The second specimen, from near the middle of the tail, is much mutilated. It measures rather more than two inches in length, and appears to have had the same form as in the Alligator.

Of the fragments of humeri, one consists of a portion of the shaft of that of the right side, and measures three inches in circumference; the other is the proximal extremity of the left humerus, and does not differ from the corresponding part in the Alligator. Its head measures rather more than two inches in its greater diameter, and a little more than one inch in its lesser diameter.

Recently Prof. Cook has sent to me for examination a small collection of Crocodile bones belonging to the collection of Rutger's College. The specimens were obtained from near Barnsboro', Gloucester County, N. J., and consist of four vertebræ, the shaft of a femur, and four broken dermal bones, apparently all from the same individual.

The vertebræ have had their arches fully coosified with the bodies, so that they may be considered as having belonged to an animal of mature age. They belonged to a smaller individual than the specimens above described, and perhaps to a different species, for several present some peculiarities of form.

Two of the vertebræ, Figs. 4, 5, Plate II, belonged in the cervical series between the fourth and last, and are probably the fourth and fifth. The bodies measure an inch and three-quarters in length, independent of their posterior convexity, and correspond in general form with those of the Alligator. The hypapophysis of the fourth, Fig. 4, is a thick semicircular ridge extending between and below the level of the parapophyses. In the fifth, Fig. 5, it is a longer, straighter, and less well developed ridge, slightly notched in the middle.

The other two vertebræ are the first and fifth dorsal, and have their body about as long as the cervicals. The first dorsal has lost its hypapophysis, spinous process, and portions of the others, but so far as it is preserved it corresponds in form with that of the Alligator. The fifth dorsal has its body more compressed laterally than in the specimen above described from Timber Creek, and the hypapophysis is absolutely very much more robust than in the latter, though the vertebra is smaller. In the Barnsboro' specimen the anterior articular concavity of the body is quadrilateral, whereas it is broadly cordiform in the Timber Creek specimen. In the former the hypapophysis is excavated in front; in the latter it is plane. These differences in two characteristic vertebræ are, perhaps, sufficient to indicate that they belong to two species.

Comparative measurements of the two vertebræ are as follows:—

	Barnsboro' Sp. Lines.	Timber Creek Sp. Lines.
Length of body inferiorly	20	22
Length of body laterally	20	22
Height of body anteriorly	17	18
Width of body anteriorly	16	22
Thickness of body at middle	12	17
Thickness of hypapophysis	9	6
Breadth of vertebral arch laterally	17	20
Width of vertebral canal	6	7
Height of vertebral canal	7	8

The specimen of the shaft of a femur is three inches and a third in circumference, and resembles the corresponding portion of the same bone in the Alligator.

The dermal bones are square, differ in size, and are coarsely foveated. Two of them form a median elevation without being carinated; the others are flat. One of the more perfect measures two inches by twenty lines; another measures two inches eight lines by two inches.

The museum of the Academy contains two mutilated bodies of posterior dorsal or of lumbar vertebræ, of mature age, from Arneytown, Burlington County, N. J., presented by T. A. Conrad. The specimens, excepting in being devoid of the hypapophysis, agree with the bodies of the dorsals above described, and are like those in the living Alligator.

In the same museum there are the bodies of three vertebræ, which have lost their arches at the sutural attachment, from Jobstown, Burlington County, N. J., presented by Dr. E. Hallowell. One of the specimens, represented in Fig. 6, Plate II, apparently of the fifth cervical vertebræ, is much less convex posteriorly than in the specimens above described, and has its parapophysis wider and much less robust. Its hypapophysis is a small longitudinally cleft tubercle. The body is nineteen lines long, sixteen wide anteriorly, and fifteen high. The remaining specimens are the bodies of two posterior dorsals or lumbars, twenty lines long, and resemble the corresponding bones in the living Alligator. In the same collection, and from the same locality and donor, there is another specimen consisting of the body of a posterior dorsal vertebra with the coosified abutments of its arch remaining. The body agrees in its form and proportions with those just described, and measures twenty-one lines in length.

The body of a posterior cervical vertebra, from the Green-sand of St. George's, Delaware, presented to the Academy by T. A. Conrad, is represented in Fig. 7, Plate II. It belonged to a young animal, and has lost its arch at the sutural conjunction. It measures fifteen lines long, and is provided with very robust parapophyses. The hypapophysis is well developed and associates the latter processes, forming together a large crescentoid ridge, deeply notched at the middle. It probably belongs to the same species as the vertebræ above described from Timber Creek.

The museum of the Academy contains a fragment of a left dental bone with a tooth, of a small Crocodile, or of a young individual of a large one, presented by C. C. Abbott. It was found in Monmouth County, N. J., and is represented in Figs. 22, 23, Plate IV. The specimen resembles in form the corresponding portion of the lower jaw of Harlan's Crocodile, of which it may be part of a quite young individual. The suture for the splenial bone, however, does not reach the symphysis as in the fragment characteristic of *Bottosaurus Harlani*—ceasing about one inch short of it. Besides three alveoli, there are preserved portions of five others, and the third behind the symphysis still retains a tooth. The latter has a compressed, conical crown, with its inner and outer surfaces defined by a prominent carina-like ridge. The surfaces are finely rugose longitudinally, and the carinæ are rugose in a divergent manner. The crown measures five lines in length and width, and a line less from without inwardly.

Another specimen belonging to the cabinet of the Academy, represented in Fig. 8, Plate II, is a fragment of a small Gavial skull from the Green-sand of Burlington County, N. J. In construction it bears a resemblance to the corresponding part of the Vincenttown skull, to which I by no means feel sure it does not belong, though it differs in some important points. The forehead, in the fragment, between the position of the post-frontals is quite flat, while it is decidedly concave in the Vincenttown skull. The frontal is less prolonged to meet the parietal than in the latter. The dividing ridge formed by the parietal between the temporal fossæ is even slightly greater than in the Vincenttown skull, while the distance between the orbits at the anterior broken end of the specimen is only two inches. The upper surface of the parietal and frontal is also more strikingly foveated than in the Vincenttown skull.

Four specimens of teeth, from Blackwoodtown, Camden County, N. J., presented to the Academy by Dr. J. L. Burtt, may probably belong to the same species as the fragment of skull just described. The more perfect are represented in Figs. 7, 8, 9, Plate I. They have the form, curvature, and proportions of the teeth of the living *Gavialis Gangeticus*, and are proportionately narrower than those of *Thoracosaurus Neocesariensis*, and are also more finely striated.

Figs. 22, 23, Plate III, represent the mutilated crowns of two teeth of a crocodilian reptile, supposed to have been obtained from a Green-sand deposit of North Carolina, submitted to my examination by Dr. Isaac Lea. One of the specimens, Fig. 22, is straight and conical, circular in transverse section, with an acute ridge in front and behind which defines the inner and outer surfaces. The latter at base are smooth, and apparently have been so at the apex, which is too much broken to determine the fact positively. The intermediate portion of the surfaces is nearly regularly fluted; the ridges separating the concave grooves extending from the dentinal substance. The base of the crown is excavated. The length of the specimen is fourteen lines and a half; its diameter at base, six lines.

The second specimen, Fig. 23, differs from the former in being somewhat curved, elliptical in transverse section, and in the fluting extending to the bottom of the crown. The apex is worn off, and the specimen in its present state is ten lines and a half long, by six lines and a half in diameter antero-posteriorly near the base.

The two teeth differ from those of *Pliogonodon*, probably also from the Green-sand of North Carolina, in which the crown is proportionately longer, and has its surfaces subdivided into narrow planes and provided with a few interrupted vertical plicæ. They differ also from those of *Polygonodon*, in which the crown of the tooth is long and narrow and its surfaces subdivided into planes without folds or striæ.

Dr. Emmons, in his Report of the North Carolina Geological Survey, page 219, fig. 38, has described and figured a large Crocodilian tooth, obtained from a bed of Miocene marl, at Elizabethtown, Bladen County, N. C. The tooth, together with some bones, Dr. Emmons nevertheless thinks originally belonged to the Green-sand formation beneath. It has a conical crown, and a robust cylindrical fang; is hollow, and moderately curved. The crown is described as circular in transverse section, and without carinæ, or acute ridges separating the inner and outer surfaces, the enamel of which is traversed with "irregular rugose ridges." The specimen is referred to the genus *Polyptychodon*, under the name of *P. rugosus.*

Another tooth, found with the preceding, described and figured in the same chapter, page 220, fig. 39, and referred by Dr. Emmons to the same animal, appears rather to have belonged to *Mosasaurus.*

Fig. 12, Plate VIII, represents a dermal plate, which, together with a small fragment of a jaw, and the mutilated crown of a tooth, were submitted to my examinatiom from the Burlington County Lyceum of Natural History. The dermal plate measures two inches by twenty lines, and is without a carina. The fragment of jaw, much mutilated, is two and a half inches long, straight, and contains the much curved fangs of two teeth. It indicates a small species of Gavial, or perhaps belonged to the young of *Thoracosaurus Neocesariensis.* The isolated crown of a tooth closely resembles that of Fig. 7, Plate I, but is rather more curved.

HYPOSAURUS.

Hyposaurus Rogersii.

Hyposaurus Rogersii, OWEN, Quart. Jour. Geol. Soc. Lond. V, 1849, 380, pl. xi, figs. 7–10.
Holcodus acutidens, GIBBES (in part), Mem. on Mosasaurus, &c., Smithsonian Contrib. II, 1850, 9, pl. iii, fig. 13

Among the fossil vertebræ, from the Green-sand formation of New Jersey, described by Prof. Owen, in the Journal of the Geological Society of London, were two specimens with biconcave bodies, which are referred to a genus of the Crocodilian family under the name of *Hyposaurus Rogersii.* Prof. Owen remarks that "the peculiar and distinctive character of these vertebræ is shown in the large size and especially the great antero-posterior extent of the hypapophysis. Its base occupies the whole extent of the median line of the inferior surface between the prominent borders of the anterior and posterior articular ends of the centrum."

Remains of this genus, on several occasions, have come under my notice, but usually in a much mutilated condition.

A small collection of bone fragments, referable to this animal, were found in the Green-sand, near White Horse, Camden County, N. J., and were presented to the Academy of Natural Sciences by W. Parker Foulke. The specimens are exceedingly friable, and consist of portions of several vertebræ, small fragments of a skull together with portions of the supra-angular bones of the lower jaw, fragments of a humerus, portion of a cervical rib, and the crowns of five teeth, all appertaining to a single individual.

One of the vertebral specimens, of the proportions of those referred by Prof. Owen to *Hyposaurus*, from the anterior part of the dorsal series, consists of the fragment of a body retaining one of the sub-concave articular faces, and the remains of the large lamelliform hypapophysis projecting like a keel from the bone inferiorly.

The best of the vertebral specimens consists of the body of a cervical vertebra with one abutment of the arch remaining. Its articular faces are half oval in outline, with the anterior one more deeply concave than the posterior, which is likewise the case in the other vertebral specimens. The length of the body is about two inches and a half, its depth posteriorly twenty lines, and its width above seventeen lines. Its sides are deeply impressed; its surface next the vertebral canal is nearly plane. The transverse processes are of robust proportions, and those below are united by a stout hypapophysis bounding the fore part of the body beneath. Posterior to the hypapophysis, the under surface of the body forms a deep concavity subdivided by a slight median carina ending in an angular apophysis posteriorly.

The supra-angular bone is quite peculiar, and appears to have largely contributed to the articulation of the lower jaw, though this is not certain, as the condition of the specimen is such that I am not positive whether the articular surface preserved in the fragment actually belongs to the supra-angular. Internally to the articular surface there is a large vertical sutural surface, either adapted to a true articular bone, or unlike the arrangement in any other known Crocodilian, it must have joined the splenial bone as in Turtles. Exterior to and in advance of the articulation of the lower jaw, the supra-angular forms a strong projecting ledge which overhangs the exterior surface of the bone and gradually diminishes over the position of the oval foramen.

The fragments of the humerus mentioned are too much injured to derive any character of importance from them.

Of the five crowns of teeth belonging to the collection the two best preserved are represented in Figs. 16, 17, Plate III. The largest resembles the teeth of the Gavial, being curved conical, nearly circular in transverse section, with prominent acute ridges defining the outer and inner surfaces, which are distinctly fluted. The smaller specimen, and such also is the character of those not represented in the plate, differs from the preceding in being compressed from without inwardly, so that its transverse section exhibits an oval outline, and it is less distinctly fluted.

Recently Dr. W. W. Lamb presented to the Academy of Natural Sciences a collection of bones, referable to a single individual of *Hyposaurus*, from the Green-sand in the vicinity of Blackwoodtown, Camden County, N. J. The specimens are very friable, in consequence of which they have been much mutilated since their discovery. They consist of portions of three cervical, as many dorsal, and five caudal vertebræ, a basilar bone, four crowns of teeth, the greater part of the shaft of a femur and fragments of several other long bones and ribs, an astragalus, two phalanges, and portions of four dermal scales.

In all the vertebral specimens the articular faces of the bodies are slightly concave, the anterior being more deeply depressed than the posterior. The cervical vertebræ, the best preserved of which is represented in Fig. 1, Plate IV, have their body nearly two inches and three-quarters long, with the form and proportions corresponding with those of the specimen previously described. The vertebral arch and canal are like the same parts in the Alligator. The spinous process, partially preserved in one specimen, ascends from a base extending the breadth of the arch and rapidly narrows as it rises.

The dorsal vertebræ belong to the posterior division of the series. The best of the specimens, represented in Figs. 4, 5, Plate IV, has the body about two and a quarter inches long, and of slightly greater depth and less width anteriorly.

The caudal vertebræ, Figs. 8, 9, 10, Plate IV, are short in relation with their depth and breadth. Their body is sub-cuboidal, with the articular ends slightly oblique; and they are provided with strong abutments for the articulation of subvertebral arches or chevron bones. The body of the best preserved specimen, Figs. 9, 10, is about two inches and a quarter long, a trifle over two inches in depth posteriorly, and less than two inches in width in the same position.

The isolated basilar bone has its condyle nearly two inches wide at base, and a little over an inch in depth.

The greater part of the shaft of a femur, Fig. 4, Plate III, is rather more than five inches in circumference at the middle, and is pervaded its entire length by a large medullary cavity.

The astragalus measures two inches and a quarter in its long diameter, twenty lines in its short diameter, and is thirteen lines thick.

A last ungual phalanx is nearly two inches in length.

The dermal plates, of which two are represented in Figs. 11, 12, Plate IV, are without carina or tubercle, gradually thin away towards the margins, and are impressed by a comparatively few large and deep foveæ.

The teeth, which accompanied the bones just described, represented in Figs. 18–21, Plate III, are curved conical, compressed from without inwardly, and have their external and internal surfaces defined by an acute ridge. They are not fluted as in the specimens previously described, and were it not for their association might readily have been supposed to belong to a different animal. They are longitudinally wrinkled, especially near the base of the crown, and more internally than externally.

The teeth described and figured by Dr. R. W. Gibbes, in the second volume of the Smithsonian Contributions to knowledge,[1] supposed to be characteristic of a

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[1] Memoir on Mosasaurus and the allied Genera, p. 9.

reptile allied to *Mosasaurus*, and named *Holcodus acutidens*, in part at least, appear rather to belong to *Hyposaurus*. Of the specimens, which Dr. Gibbes has submitted to my inspection, that from New Jersey, I think, undoubtedly belongs to the last mentioned genus. The other specimen, from the Cretaceous formation of Alabama, though agreeing in its form and proportions with the teeth above described, may, nevertheless have belonged to a *Mosasaurus*.

The collection of the Academy contains a dorsal vertebra, represented in Figs. 6, 7, Plate IV, from the Green-sand of Burlington County, N. J., which has the same form and proportions as the corresponding vertebræ above mentioned, but is smaller. The specimen probably occupied a more anterior position in the series; though it may have belonged to a smaller species of the genus. The cabinet of the Academy also contains the body of a dorsal vertebra, from the Green-sand of Newcastle County, Del., which has the same form as the Burlington County specimen, but is the fourth of an inch longer.

Since writing the foregoing I have received for examination a small collection of remains of *Hyposaurus*, belonging to Rutger's College, New Brunswick, N. J. The specimens were sent by Prof. Cook, who informs me that they were obtained from a marl pit, at Tinton Falls, Monmouth County, N. J. The specimens have the same friable character as those previously described, and they appear to have belonged to two different individuals: one quite young, the other of maturer age. Those of the young individual consist of several fragments of the occipitals, a cervical rib resembling those of the Mississippi Alligator, and the body of a posterior dorsal two inches long. Those of the maturer animal consist of a posterior cervical and a fourth dorsal vertebra, the bodies of three posterior dorsals, and the shaft of a femur.

The posterior cervical, represented in Fig. 2, Plate IV, corresponds in size, form, and details of structure with those previously described. The length of its body, which is slightly more concave posteriorly than anteriorly, is three inches, and the length of the specimen between the anterior and posterior articular processes is three inches and three-quarters. The hypapophysis, somewhat mutilated, appears not to have been proportionately better developed than the corresponding processes in the cervical series of the Mississippi Alligator.

The fourth dorsal vertebra, Fig. 3, Plate IV, has lost one-half of its vertebral arch with the spinous process, and the other half of the arch is separable at its suture with the body. The latter is two inches and a quarter in length below and two inches and a half at its junction with the arch. The two ends are nearly equally concave, and between them there extends a broad laminar hypapophysis, as represented in the specimens upon which Prof. Owen proposed the genus, but as in these, unluckily the process is broken so that we are unable to determine its length.

The bodies of the three posterior dorsals are rather over two inches in length, and exhibit the sutures from which the vertebral arches have been detached. They are more concave anteriorly than posteriorly, in this and other characters agreeing closely with those previously described.

The shaft of a femur corresponds closely with that already described both in size and form.

DISCOSAURUS.

Discosaurus vetustus.

Discosaurus vetustus, Leidy, Proc. Acad. Nat. Sci. Phila. 1851, 326.

The remains of a large Saurian, apparently nearly related to the *Plesiosaurus* of Europe, discovered in the American Cretaceous deposits, have occasionally come under my notice. Dr. Harlan has described and figured a vertebra, obtained, together with several others, from Mullica Hill, N. J., which he referred to the *Plesiosaurus*.[1] The specimens, upon which this view was founded, are preserved in the museum of the Academy of Natural Sciences, and prove to belong to a Cetacean, of the Dolphin family. Subsequently Dr. DeKay described and figured a fragment apparently of a cervical vertebra, from the Green-sand of New Jersey, evidently belonging to the Saurian to which I allude, and which he recognized as being allied to *Plesiosaurus*.[2]

The collection of the Academy of Natural Sciences contains a few remains of the Saurian indicated from four different localities, as follow:—

1. The mutilated bodies of two caudal vertebræ, as I suppose them to be, from the Cretaceous deposits of Alabama, presented by Prof. Joseph Jones, of Georgia.

The specimens, represented in Figs. 4, 5, 6, Plate V, have the body in the form of a transverse section of a cylinder, compressed from above downward, with the sides and under part slightly narrowed towards the middle. The articular extremities are transversely elliptical and moderately concave, but have prominently convex borders. They are constricted or defined from the rest of the body by a narrow groove, which gives them the appearance of distinct plates or disks applied to and terminating the body. From this peculiar appearance, the name of *Discosaurus* was proposed for the genus to which the vertebræ belong. At the under part of the body, as seen in Fig. 5, the groove is inflected on each side apparently with the view of producing facets for a chevron bone. It is this apparent adaptation of the parts to the articulation of chevron bones which has led me to consider the vertebræ under consideration as caudals, otherwise from their resemblance to the cervical vertebræ of *Plesiosaurus pachyomus*, as represented by Prof. Owen,[3] I should have viewed them as belonging to the cervical series.

Between the position of the inflections to accommodate the chevron bones, the under part of the body forms a pair of feeble ridges, the intervening surface of which presents on one side a single venous foramen communicating by a branching vertical canal with the spinal canal. The latter, in both specimens under examination, is too much broken to judge of its form, and no other information is to be ascertained from the abutments of the vertebral arch other than that they were completely coösified with the body. The side of the body is produced into a large conical protuberance

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[1] Journ. Acad. Nat. Sci. Phila. IV, 1824, 232, pl. xiv, fig. 1; Med. Phys. Res. 1835, 382. See note, page 1, of this Memoir.

[2] An. Lyc. Nat. Hist. New York, III, 1828, 165, pl. iii, fig. 11.

[3] British Fossil Reptiles, Enaliosauria, pl. 28.

excavated to its base into a transversely elliptical costal pit, bounded by a prominent acute border. The pit occupies the middle portion of the body from above downward, and extends two-thirds its length, reaching nearer the anterior than the posterior articular surface.

Measurements, derived from the two specimens which are almost identical in size as well as form, are as follows:—

	Lines.
Length of body between the grooves defining the articular extremities	19
Extreme length of body between the prominent margins of the articular extremities	24
Breadth of articular extremities	31
Height of articular extremities	26
Estimated breadth of spinal canal	6
Transverse diameter of costal pits	14
Vertical diameter of costal pits	11

2. A vertebra, represented in Figs. 10, 11, 12, Plate V, rather larger than the preceding, but nearly identical in form, from the lower Cretaceous of Mississippi, presented to the Academy by Prof. M. Tuomey. In this specimen the articular extremities of the body are nearly flat surfaces, being much less depressed towards the centre and much less prominent towards the periphery than in the Alabama specimens. It differs also from the latter in having the articular surfaces terminating in an acute margin and not defined from the rest of the body by a groove. The body beneath, Fig. 10, presents inflections apparently for the articulation of chevron bones, those posterior being large, while those anterior are but slight. The vertebral arch, partly preserved in the specimen, is coosified with the body. It presents no conspicuous mark of its original separation, and a continuous slope extends from the side of the arch upon that of the body to the upper margin of the costal pit.

The measurements of the specimen are as follows:—

	Lines.
Length of the body at the acute margins of the articular extremities	24
Extreme length of the body at the prominent periphery of the articular extremities	26
Breadth of the articular extremities	36
Height of the articular extremities	29
Diameter of spinal canal	7
Transverse diameter of costal pits	15
Vertical diameter of costal pits	9

3. A much mutilated body of a vertebra from Choctaw Bluff, Clarke Co., Alabama, presented by Prof. M. Tuomey to the Academy. The specimen has the same form as that just described, excepting that its articular faces are more concave and it is considerably larger.

Its measurements are as follows:—

	Lines.
Length of body	31
Breadth of articular extremities	44
Height of articular extremities	34
Width of spinal canal	10
Transverse diameter of costal pits	17
Vertical diameter of costal pits	11

4. Two vertebræ, a carpal and two metacarpal bones and a phalanx, apparently all from the same individual. The specimens were found, with others, in Burlington County, N. J.

Of the vertebræ, the one represented in Figs. 7, 8, 9, Plate V, is almost identical in form and size with the first described specimens from Alabama. The articular surfaces of its body present intermediate characters to those of the Alabama specimens and the one from Mississippi. As previously stated, in the former, the articular surfaces are defined by a narrow groove from the rest of the body, of which an acute edge forms one boundary of the groove and the prominent convex periphery of the articular surface the other. In the Mississippi specimen the corresponding groove is nearly obsolete, so that the articular surfaces appear defined from the rest of the body by an acute edge. In the Jersey specimen the acute edge forms a conspicuous linear ridge, and a feeble groove defines this from the articular surfaces. The latter are less depressed towards the centre, and less prominent at the periphery than in the Alabama specimens, but in both characters are more so than in the Mississippi specimen. In the Jersey specimen the inflections for the apparent accommodation of chevron bones are deeper than in the Alabama specimens, and give the under part of the body at its extremities a remarkably festooned appearance, as represented in Fig. 8. The body inferiorly, between the inflections, in front and behind, does not exhibit the ridges so prominently as in the other specimens, but is otherwise the same.

The measurements of the vertebra are as follows:—

	Lines.
Length of the body in the median line inferiorly between the acute edges	22
Length between the lateral inflections of the latter	14
Length of the body laterally between the acute edges	20
Extreme length of the body between the prominent margins of the articular extremities	24
Breadth of the articular extremities	34
Height of the articular extremities	27
Width of spinal canal	6
Transverse diameter of costal pits	13
Vertical diameter of costal pits	10

The other vertebra, represented in Figs. 1, 2, 3, Plate V, much larger than the former, appears to belong to the back part of the cervical series. The body is a transverse section of a cylinder flattened from above downward and moderately narrowed at the sides and underneath towards the middle. The articular extremities are nearly plane surfaces, transversely elliptical, but emarginate above, and are defined from the rest of the body by a sub-acute border. The general level of the posterior surface is slightly depressed, and its periphery is slightly convex. The anterior surface is a little more depressed, but presents a slight central prominence. The under part of the body is less depressed than the sides, and it presents three large venous foramina. The vertebral arch is coosified with its body on a level with the floor of the spinal canal, which is almost a plane surface. The spinal canal is large and ovoid in outline. A portion of the spinous process, preserved in the specimen, proves it to be a strong, broad plate. It is deeply grooved behind at its root for an elastic ligament. The greater portion of a remaining posterior articular process indicates this to be of small size, and it has its facet directed downward and outward.

The side of the body is extended into a large process excavated to its base into a vertical, ear-shaped, concave, costal pit, bounded by an elevated, acute margin. The vertical diameter of the pit is equal to two-thirds that of the body, and its transverse diameter equal to half the length of the latter. The upper extremity of the pit is formed by a trilateral process projecting outwardly from the root of the vertebral arch, and is separated from the rest of the pit by a deep, crescentoid, transverse fissure, remaining as part of the suture through which the arch is united with the body of the vertebra.

The measurements of this vertebra are as follows:—

	Lines.
Length of the body	31
Breadth of the articular extremities	43
Height of the articular extremities	33
Breadth of costal pits	15
Height of costal pits	27
Breadth of spinal canal	11
Height of spinal canal	12

The carpal bone, represented in Figs. 13, 14, Plate IV, resembles those of *Plesiosaurus.* It is a thick hexahedral tablet, with the broad surfaces concave and rugged. The borders are half the width of the broad surfaces, and present parallel rows of nutritious foramina. The bone measures in its greater breadth thirty lines, in its lesser twenty lines, and its thickness ranges between twelve and sixteen lines.

The metacarpal bones, represented in Figs. 15, 16, 17, likewise resemble those of *Plesiosaurus.* They are quadrilateral columnar bones, with the sides concave longitudinally. The extremities are quadrate in outline, and their surfaces exhibit parallel rows of nutritious foramina.

The phalanx, represented in Fig. 18, also resembles those of *Plesiosaurus.* It is a slightly compressed cylindrical column, expanding from the middle towards both extremities.

The carpal, metacarpal, and phalangeal bones indicate that they were articulated by cartilage, and together with the other bones of the extremity formed a paddle like those of *Plesiosaurus.*

It is not improbable that I may have included, in the account of *Discosaurus vetustus*, the remains of more than one species, but the material at command appeared to me insufficient to justify a separation.

CIMOLIASAURUS.

Cimoliasaurus magnus.

Cimoliasaurus magnus, Leidy, Proc. Acad. Nat. Sci. Phila. 1851, 325; 1854, 72, pl. ii, figs. 4, 5, 6.

Vertebræ differing from any of those described in the preceding pages, and belonging to a huge Saurian, are frequently found in the Green-sand deposits of

New Jersey. The vertebræ have slightly biconcave bodies and are usually well preserved, though all the specimens I have had the opportunity of examining have had their arches and processes broken off, apparently after their discovery. Of such vertebræ thirteen specimens, from Burlington County, N. J., were presented to the Academy of Natural Sciences by Dr. S. G. Morton. They appear to have belonged to the same individual, and consist, as I suppose them to be, of two dorsals and eleven lumbars.

The body of the dorsal vertebræ, Figs. 13-16, Plate V, is the transverse section of a cylinder compressed from above downward and contracted towards the middle, resembling in form the body of the cervical vertebra referred to *Discosaurus.* The articular faces are transversely oval, slightly emarginate above, and are more concave than in the cervical vertebra of *Discosaurus.* They present a central prominence, are bevelled off at the border, and are defined by a subacute edge from the rest of the body. A pair of large venous foramina underneath the latter communicate with channels opening by a single large orifice in the spinal canal, which is depressed towards the middle and wide. The vertebral arch has been coossified with the body, but its loss prevents me from ascertaining anything in regard to its form. In one of the specimens, as represented in Figs. 13, 14, 15, there projects from the middle of the side of the body a short, robust, cylindroid transverse process, terminating in a large irregular facet for the articulation of a rib. In the other vertebra, Fig. 16, probably a more anterior one, the transverse process is broken, but its base indicates it to have been of greater vertical extent than in the former specimen, though not quite so wide, nor does it extend so low, but above appears nearly to have reached the abutment of the vertebral arch.

The size of the two specimens is nearly equal, their measurements being as follows:—

	Lines.
Length of the vertebral body	32–33
Breadth of articular surfaces	52
Height	42
Width of spinal canal at the middle	12
Width of spinal canal at the extremities	15
Breadth between articular facets of transverse processes	72

The eleven lumbar vertebræ, of which the largest and smallest specimens are represented in Figs. 17–19, Plate V, and 16–18, Plate VI, do not form an unbroken series, but the specimens successively diminish in size from nearly that of the dorsals just described, to a size rather less than the supposed caudals of *Discosaurus.* They are nearly identical in form throughout. The more anterior have the body absolutely somewhat longer than in the dorsals, though the other diameters are diminished. The articular extremities are also slightly more dished than in the dorsals, and almost devoid of the central prominence. The venous foramina on the under part of the body are nearer together, and the intervening portion of bone appears pinched into a convex ridge. The more posterior specimens, which may be regarded as caudals, have the articular extremities of their body rather more concave, and underneath they do not form so prominent a ridge between the position of the two venous foramina.

In all the lumbar vertebræ the abutments of the vertebral arch are fully coossified with their body, leaving no well-marked trace of the former sutural connection. The spinal canal is wide, and is depressed at the floor towards the middle, where it exhibits one or two large venous foramina. In all the specimens the transverse processes have been broken off, but in all, their remaining bases are seen projecting from the lower part of the side of the body. They spring from nearly the whole width of the body, with which they were completely coossified, though they present the appearance as if they formerly possessed a sutural attachment. They were evidently robust and strong, and were directed obliquely outward and downward.

The sides of the body of the vertebræ form, together with the sides of the vertebral arch and the upper part of the transverse processes, a nearly uniform slope, broken only by a slight elevation formed by the apparent sutural coossification of the transverse process with the body. The under part of the body between the transverse processes nearly forms a level surface, more or less elevated into a ridge between the venous foramina, and depressed along a line with the position of the latter.

Measurements, derived from the largest and the smallest of the series of eleven lumbars, are as follows:—

	LARGEST. Lines.	SMALLEST. Lines.
Length of body	35	24
Breadth of articular surfaces	44	31
Height of articular surfaces	36	22
Width of spinal canal	10	8

The vertebræ, above described, were briefly noticed a few years ago in the Proceedings of the Academy of Natural Sciences, volume V, page 325, and referred to a Reptile under the name of *Cimoliasaurus magnus.*

Fourteen vertebræ of the same Saurian as the preceding have been submitted to my inspection by Mr. O. R. Willis, through Prof. Cook. They all evidently belonged to the same individual, and were obtained from the Green-sand, near Freehold, Monmouth Co., N. J. Six of the specimens are dorsal, the remainder lumbar vertebræ. Of the former, three appear to have had their transverse processes at the conjunction of the vertebral arch and body; the others had them situated successively lower on the sides of the body.

Two of the more anterior dorsals are represented in Figs. 1, 2, 3, 4, Plate VI. They exhibit a slight want of symmetry, which is the case also with another anterior dorsal, but this character is a deformity, or mere individual peculiarity. The body is a little longer and higher, in relation with the breadth, than in the dorsals above described, and hence presents a more cylindrical form. The articular extremities are moderately dished, and have a somewhat prominent annular margin. They are nearly circular, but notched above, and are sharply defined by a subacute ridge from the rest of the body. The bottom and sides of the latter are narrowed towards the middle or are concave longitudinally, and they present a number of foramina, varying in size, which communicate with venous channels opening into the spinal canal. The broken abutments of the vertebral arch are much broader and stronger, in accordance with their being required to sustain the transverse processes, than in the more posterior dorsals. The spinal canal is large and depressed towards the middle of the floor.

The measurements of one of the anterior dorsals, which are nearly of the same size, are as follows:—

	Lines.
Length of the vertebral body	36
Breadth of articular surfaces	51
Height of articular surfaces	45
Width of spinal canal	12

A more posterior dorsal vertebra, represented in Fig. 5, Plate VI, differs from the preceding in the less length and depth of the body and the slightly greater breadth, but chiefly in the lower position of the transverse process, which extends from the vertebral arch to near the middle of the side of the body. The measurements of this specimen are as follows:—

	Lines.
Length of the vertebral body	33
Breadth of the articular surfaces	54
Height of the articular surfaces	43

The remaining two posterior dorsal vertebræ, represented in Figs. 6–9, Plate VI, appear to be from near the termination of the series. They have the same form of body as the Burlington County specimens of posterior dorsals, above described, with which they also nearly agree in size. The transverse processes are short, robust, irregularly cylindroid protuberances, projecting from the lower part of the side of the body and terminating in an articulating facet for a rib. In the foremost of the two vertebræ, Fig. 7, the facets are sub-circular and irregularly convex; in the other, Fig. 9, they are transversely oval and irregularly concave. On the under surface of the body of the former, Fig. 6, there are two large foramina on each side communicating with venous channels opening into the spinal canal; in the latter, Fig. 8, the under part of the body presents two very large venous foramina, between which the bone forms a convex ridge, not existing in the preceding vertebra.

Measurements of the two posterior dorsal vertebræ are as follows:—

	Lines.	Lines.
Length of the body	33	35
Breadth of the body	56	52
Height of the body		40
Width of spinal canal		11
Vertical diameter of facet for the rib	18	16
Transverse diameter of facet for the rib	18	20

The eight lumbar vertebræ, of which the largest and smallest specimens are represented in Figs. 10–15, Plate VI, form a nearly unbroken series, and followed close after the dorsal specimens just described. They correspond in form and constitution with the Burlington County specimens, except that the median part of their body beneath, between the position of the venous foramina, forms a more prominent ridge.

The measurements of the largest and smallest specimens, or the first and last of the series, are as follows:—

	LARGEST. Lines.	SMALLEST. Lines.
Length of the vertebral body	35	31
Breadth of articular extremities	50	41
Height of articular extremities	39	28
Width of spinal canal	9	8

It is probable that the vertebræ, above described as lumbars, may be regarded in part as representing sacrals and caudals. Both dorsals and lumbars bear some resemblance to the corresponding vertebræ of Cetaceans, except that in these the transverse processes project from the middle of the sides of the body of the lumbars instead of the lower part. The long series of vertebræ of *Cimoliasaurus* consisting of lumbars apparently gradually merging into caudals, perhaps indicate the absence of a true sacrum and posterior extremities, as in Cetaceans.

I cannot avoid the suspicion that the specimens referred to *Cimoliasaurus magnus* do not belong to the same great reptile as those considered as characteristic of *Discosaurus vetustus.* The supposed caudals of the latter I have suspected to be anterior cervicals notwithstanding the apparent provision for the articulation of chevron bones. If all the vertebral specimens be viewed as belonging to one animal, they represent cervicals, dorsals, and lumbars of *Discosaurus*, otherwise they represent a cervical and caudals of the latter, and dorsals and lumbars of *Cimoliasaurus.*

The vertebræ described as caudals of *Discosaurus* have almost the same size and nearly the same form as the smaller lumbars or caudals attributed to *Cimoliasaurus.* A rib of proportionate size, coosified with the costal pit in the former, would give them a striking resemblance to the latter, except that in *Cimoliasaurus* the costal or transverse processes project from the lower part of the sides of the body, whereas in *Discosaurus* the costal pits are situated at the middle of the sides of the body. The vertebræ, however, differ in other important particulars. Besides the absence of the conspicuous inflections (supposed to have been intended to accommodate chevron bones) in the caudals of *Cimoliasaurus* the body beneath is nearly level between the transverse processes, while in *Discosaurus* it is strongly convex in the corresponding position.

No portions of the skull nor specimens of teeth have been discovered which, with any probability, could be referred either to *Discosaurus* or *Cimoliasaurus.*

PIRATOSAURUS.

Piratosaurus plicatus.

I recently received from the Smithsonian Institution, for examination, a small collection of fossils, which, in a note accompanying the specimens, are stated to have been obtained from the drift of Red River Settlement, about fifty miles south of Selkirk Settlement, and are further labelled as from the Red River of the North. The specimens consist of a peculiar Crocodilian tooth, and others agreeing in form with those referred to *Otodus appendiculatus*, *Corax appendiculatus*, and *Ptychodus*

Mortoni, which would indicate the fossils as appertaining to the Cretaceous era. The reptilian tooth, and several of those of the fishes, are partially imbedded in hard iron pyrites.

The Crocodilian tooth, represented in Fig. 8, Plate XIX, presents the ordinary form of the teeth of recent Crocodiles and Alligators, being curved conical. The crown, or enamelled portion of the tooth, worn away at the point, in its present state measures seventeen lines long, and the remaining portion of the somewhat gibbous fang is half an inch long. I can detect no appearance of acute ridges separating the inner and outer faces of the crown, though such may have existed. The enamel towards the apex is smooth, but at rather more than the basal half of the crown it is thrown into well-defined, slightly tortuous, longitudinal folds or ridges, reminding one of the appearance of those in the teeth of *Polyptichodon*. Between the folds the surface exhibits shallow punctures. The diameter of the tooth at the base of the crown is eight lines. The interior of the tooth is hollow as in the teeth of living Crocodiles.

MOSASAURUS.

Saurian animal, resembling the famous fossil reptile of Maestricht, Mitchell, Observ. Geol. N. America, 1818, 384, 385, pl. viii, fig. 4.

Saurian reptile, resembling the Maestricht Monitor, Harlan, Journ. Acad. Nat. Sci. 1825, Vol. IV, 235, pl. xiv, figs. 2, 3, 4; Med. and Phys. Researches, 1835, 384.

Mosasaurus, De Kay, Ann. Lyc. Nat. Hist, 1828–36, Vol. III, 135, pl. iii, figs. 1, 2.—Morton, Am. Jour. Sci. 1830, Vol. XVIII, 246; Synop. Org. Rem. 1834, 27, pl. xi, figs. 7, 9.—Harlan, Trans. Geol. Soc. 1835, 81; Med. and Phys. Res. 1835, 285.—Emmons, North Carolina Geol. Survey, 1858, 217.

Geosaurus Mitchelli, De Kay, An. Lyc. Nat. Hist. 1828–36, Vol. III, 138; Zool. New York, 1842, Part III, 28, pl. 22, figs. 55, 56.—Harlan, Trans. Geol. Soc. 1835, 82; Med. and Phys. Res. 1835, 285; Edinb. Phil. Journ. 1834, Vol. XVIII, 32.—Pictet, Paléontologie, 1853, Vol. I, 506.

Geosaurus, Morton, Am. Jour. Sci. 1830, Vol. XVIII, 246; Syn. Org. Rem. 1834, 28.

Ichthyosaurus missouriensis, Harlan, Trans. Am. Phil. Soc. 1834, Vol. IV, 405, pl. xx, figs. 3–8; Trans. Geol. Soc. 1835, 80; Med. and Phys. Res. 1835, 284, 348, figs. 1–6.

Mosasaurus Dekayi, Bronn, Lethæa Geog. 1838, Vol. II, 760.—Gibbes, Mem. on Mosasaurus; Smithsonian Contributions, 1851, Vol. II, 8, pl. i, figs. 2, 6.

Batrachiosaurus, Harlan, Lond. and Edinb. Philos. Mag. 1839, Vol. XIX, 302.

Batrachiotherium, Harlan, Bul. Soc. Geol. 1839, Vol. X, 90.

Mosasaurus major, De Kay, Zool. New York, 1842, Pt. III, 28, pl. 22, figs. 57, 58.

Mosasaurus occidentalis, Morton, Proc. Acad. Nat. Sci. 1844, 133.

Batrachiosaurus missouriensis, Meyer, Jahrb. Min. 1845, 312.

Mosasaurus neovidii, Meyer, Jahrb. Min. 1845, 312.

Mosasaurus Maximiliani, Goldfuss, Nov. Act. Acad. K. L. C. Nat. Cur. 1845, Vol. XXI, 179, pl. vi, vii, viii, ix, figs. 1–3.—Meyer, Jahrb. Min. 1845, 312; 1847, 122.—Owen, Jour. Geol. Soc. Lond. 1849, Vol. V, 382, pl. x, fig. 5.—Gibbes, Mem. on Mosasaurus; Smithsonian Contributions, 1851, Vol. II, 6, pl. I, fig. 7.—Pictet, Paléontologie, 1853, Vol. I, 505.—Emmons, North Carolina Geol. Surv. 1858, 217, figs. 36*a*, 37.

Mosasaurus Camperi, Pictet, in part, Paléontologie, 1845, Vol. II, 64.

Mosasaurus Hofmanni, Pictet, in part, ibidem.

Atlantochelys Mortoni, Agassiz, Proc. Acad. Nat. Sci. 1849, 169.

Mosasaurus minor, Gibbes, Mem. on Mos.; Smithsonian Contributions, 1851, Vol. II, 7, pl. i, figs. 3, 4, 5.

Mosasaurus Couperi, Gibbes, ibidem, pl. ii, figs. 4, 5.

Mosasaurus carolinensis, Gibbes, ibidem, 8, pl. ii, figs. 1, 2, 3.

Holcodus acutidens, Gibbes, in part, ibidem, 9, pl. iii, figs. 6–9.

? *Amphorosteus Brumbyi*, Gibbes, ibidem.

Mosasaurus Mitchelli, Leidy, Proc. Acad. Nat. Sci. 1859, 92.

Mosasaurus missouriensis, Leidy, ibidem, 1857, 90; 1859, 92.

Elliptonodon compressus, Emmons, North Carolina Geol. Surv. 1858, 222, figs. 41, 42.

Drepanodon impar, Leidy, Proc. Acad. Nat. Sci. 1856, 255.—Emmons, North Carol. Geol. Surv., 1858, 224, figs. 45, 46.

Lesticodus impar, Leidy, Proc. Amer. Philos. Soc. 1859, VII, 10.

Nearly a century has elapsed since the discovery, in the Cretaceous deposits of Europe, of the aquatic Reptile, the *Mosasaurus*, or Lizard of the Meuse, but even at the present time our knowledge of the skeleton is incomplete. The most important of the remains found in Europe consists of the greater part of an enormous skull, including the jaws, together with the teeth, obtained from the quarries of St. Peter's Mount, near Maestricht. The specimen, to which an unusual degree of historic value is attached, is commonly known as the head of the Maestricht Monitor, and is now preserved in the museum of the Jardin des Plantes, Paris. It has been the subject of representation and description by Buchoz,[2] Faujas-Saint-Fond,[3] Cuvier,[4] Buckland,[5] Gervais,[6] Pictet,[7] Bronn,[8] and others. Series of vertebræ of the *Mosasaurus*, comprising most of those from different parts of the column, found in association with the head just mentioned, have also been described by Cuvier.[9]

In the United States remains of the genus *Mosasaurus*, usually consisting of isolated teeth, small fragments of jaws, and mutilated vertebræ, have been frequently discovered in deposits of the Cretaceous period, and have been indicated

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[1] M. Faujas-Saint-Fond, in his Natural History of St. Peter's Mount, gives the following account of the discovery and subsequent destination of the fossil: "In one of the galleries or subterraneous quarries of St. Peter's Mount at Maestricht, at the distance of about five hundred paces from the principal entrance, and at ninety feet below the surface, the quarrymen exposed part of a skull of a large animal imbedded in the stone. They stopped their labors to give notice to Dr. Hoffman, a surgeon at Maestricht, who had for some years been collecting fossils from the quarries, and who had liberally remunerated the laborers for them. Dr. Hoffman, observing the specimen to be the most important that had yet been discovered, took every precaution to secure it entire. After having succeeded in removing a large block of stone containing it, and reducing the mass to a proper condition, it was transported to his home in triumph. But this great prize in natural history, which had given Dr. Hoffman so much pleasure, now became the source of chagrin. A canon of Maestricht, who owned the ground beneath which was the quarry whence the skull was obtained, when the fame of the specimen reached him, laid claim to it under certain feudal rights and applied to law for its recovery. Dr. Hoffman resisted, and the matter becoming serious, the chapter of canons came to the support of their reverend brother, and Dr. Hoffman not only lost the specimen but was obliged to pay the costs of the law-suit. The canon, leaving all feeling of remorse to the judges for their iniquitous decision, became the happy and contented possessor of this unique example of its kind."

M. Faujas-Saint-Fond continues, "Justice, though slow, arrives at last. The specimen was destined again to change its place and possessor. In 1795 the troops of the French Republic, having repulsed the Austrians, laid siege to Maestricht and bombarded Fort St. Peter. The country house of the canon, in which the skull was kept, was near the fort, and the general being informed of the circumstance gave orders that the artillerists should avoid that house. The canon, suspecting the object of this attention, had the skull removed and concealed in a place of safety in the city. After the French took possession of the latter, Freicine, the representative of the people, promised a reward of six hundred bottles of wine for its discovery. The promise had its effect, for the next day a dozen grenadiers brought the specimen in triumph to the house of the representative, and it was subsequently conveyed to the museum of Paris."

[2] Dons de la Nature, Tab. 68.

[3] Histoire Naturelle de la Montagne de St. Pierre de Maestricht, Pl. IV.

[4] Ossemens Fossiles, Ed. 4, Atlas T. 2, Pl. 246, Fig. 1.

[5] Bridgewater Treatise, Pl. 20.

[6] Zoologie et Paléontologie Françaises, T. III, Pl. 60, Figs. 3–5.

[7] Traité de Paléontologie, Atlas, Pl. XXVI, Fig. 3.

[8] Lethæa Geognostica.

[9] Ossemens Fossiles, Ed. 4, T. 10, p. 151.

or described by Mitchell,[1] De Kay,[2] Harlan,[3] Morton,[4] Gibbes,[5] and Emmons.[6] The

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[1] Observations on the Geology of North America, by Samuel L. Mitchell, published in the American edition of the Essay on the Theory of the Earth, by Cuvier, New York, 1818. Prof. Mitchell was the first to indicate the existence of remains of *Mosasaurus* in the United States. In Plate VIII, Fig. 4, he represents the tooth of a *Mosasaurus* from the foot of Neversink Hills, New Jersey, and refers to it, p. 384, as resembling the teeth of the famous fossil reptile of Maestricht.

[2] Annals Lyceum Nat. Hist. New York, Vol. III, p. 135, Pl. III, Figs. 1, 2. Dr. De Kay, besides describing and figuring a tooth, from Monmouth County, New Jersey, which he refers to *Mosasaurus*, also gives a description and representation of a tooth, p. 138, Pl. III, Figs. 3, 4, which he refers to *Geosaurus*, but which I am inclined to suspect also belongs to the former genus.

[3] Journal Acad. Nat. Sciences, Philadelphia, Vol. IV, p. 235, Pl. XIV, Figs. 2–4. Dr. Harlan represents a tooth from the vicinity of Woodbury, New Jersey, which he says resembles in every respect the teeth of the Maestricht Monitor. In his Med. and Phys. Researches, p. 285, he refers the same specimen to the genus *Mosasaurus*.

[4] Synopsis of Organic Remains, p. 27, 28, Pl. XI, Figs. 7, 9, 10. In this work Dr. Morton simply refers to and reproduces the specimens described by Drs. De Kay and Harlan. In the Proc. Acad. Nat. Sci. Philadelphia, Vol. II, p. 132, Dr. Morton refers to a collection of remains of *Mosasaurus* from New Jersey, forming part of the material of the above memoir. From differences observed in comparison with the European *Mosasaurus*, the author refers them to a distinct species under the name of *M. occidentalis*.

[5] Memoir on Mosasaurus and the allied Genera. By Robert W. Gibbes, M. D. Smithsonian Contributions, Vol. II. The author indicates, describes, and figures a number of specimens, which he refers to several distinct species of *Mosasaurus*. Most of the specimens were found in the Cretaceous deposits, or are readily referred thereto, but several he mentions as having been derived from the Eocene formations of Ashley R., S. C., and Wilmington, N. C., but neither describes nor figures them. I have as yet seen no trace of *Mosasaurus* remains from any of the Tertiary deposits of the United States.

A small vertebra, with an attached portion of another, from the Cretaceous formation of Alabama, together with fragments of two small teeth, from unknown localities of Alabama and Georgia, represented in Pl. I, Figs. 3, 4, 5, are referred by Dr. Gibbes to a species with the name of *Mosasaurus minor*.

Two specimens, the summits of large teeth, represented in Pl. II, Figs. 4, 5, from the Cretaceous formation of the Chattahoochie R., Georgia, are referred to a species under the name of *Mosasaurus Couperi*.

An uncharacteristic fragment of a large jaw, represented in Pl. II, Figs. 1, 2, 3, is referred to a species with the name of *Mosasaurus carolinensis*. The specimen is stated to have been found in association with Cetacean remains in the Pliocene deposit overlying the Cretaceous formation in the vicinity of Darlington, S. C. As observed by the author, "it was most probably derived from the latter formation;" and he adds, "its appearance and the mineralization of its structure render it probable that it came originally from the Cretaceous." The same explanation, I am inclined to believe, would apply to the vertebra which Dr. Gibbes mentions as having been found in the Eocene deposit of Wilmington, N. C.

The allied genera of the memoir are named *Holcodus*, *Conosaurus*, and *Amphorosteus*. The tooth, represented in Pl. III, Fig. 13, from the Cretaceous formation of New Jersey, referred to *Holcodus*, belongs to the Crocodilian *Hyposaurus*. The tooth, represented in Figs. 6–9, from the Cretaceous of Alabama, also referred to *Holcodus*, I suspect belongs to *Mosasaurus*. The teeth, represented in Pl. III, Figs. 1–5, from the Eocene deposit of the Ashley R., S. C., referred to *Conosaurus*, I have proved, through microscopic examination of the structure, to belong to a fish. The vertebræ, represented in Pl. III, Figs. 10–16, from the Cretaceous deposit of Alabama, referred to *Amphorosteus*, may probably prove to be different from those of *Mosasaurus*, but at present I consider the matter doubtful.

[6] Report of the North Carolina Geological Survey, by E. Emmons, p. 217, Figs. 36*a*, 37. The

most important remains, comprising the greater part of a skeleton, consisting of a nearly entire skull and eighty-seven vertebræ, were found, by Major O'Fallon, on the Upper Missouri, in the vicinity of Big Bend, and were presented by him to Maximilian, Prince of Wied, who was then travelling in America. Conveyed to Europe, the remains were presented by the Prince to the Museum of the Academy of Naturalists of Bonn, and were described in the Transactions of the Academy by Dr. August Goldfuss.[1]

Cuvier views the skull of the great Maestricht *Mosasaurus* as intermediate in anatomical characters to that of the existing *Monitor* and *Iguana*.[2] The length of the lower jaw he gives as three feet nine inches,[3] and estimates the skull to have been nearly four feet.[4] On each side of the lower jaw there are fourteen teeth;[5] to the upper maxillary bone eleven teeth, and as it is estimated that there may have been three additional teeth to each side of the inter-maxillary bone, the number would be the same in the upper as in the lower jaw.[6] The pterygoids, as in the *Iguana*, also possess teeth, of which Cuvier states there were eight to each bone.[7]

The skull of the Missouri *Mosasaurus* is about half the length of that of the Maestricht *Mosasaurus*, but Dr. Goldfuss assumes too much when he says the complete ossification of all parts, as well as the frequently perceptible solidification of the teeth, prove that the individual had reached maturity,[8] for the skull and teeth of Saurians exhibit the same characters of ossification and development from youth to extreme age. As remarked by Owen, "the characters of immaturity are not manifested by the cold-blooded animals in their osseous and dental systems as they are in the warm-blooded and higher organized mammalia."[9]

In the jaws of the Missouri *Mosasaurus* there are the remains of eleven teeth above and below, and supposing three more to have existed in the anterior extremities of the jaws, which were lost, the number would be equal to that of the Maestricht *Mosasaurus*. The pterygoid bones, according to Dr. Goldfuss, are each occupied with the remains of ten teeth, being two more than the number mentioned by Cuvier as existing in the Maestricht skull.

The vertebræ of *Mosasaurus* have their bodies concave in front and convex behind. Cuvier[10] estimates the number to have been about one hundred and thirty-three. These he divides as follows: The atlas and axis; eleven vertebræ of the neck and thorax distinguished by the presence of an inferior apophysis or hypapophysis together with articular and transverse processes; five similar vertebræ without the

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vertebra, represented in Fig. 34*a*, referred to *Macrosaurus*, the tooth, represented in Fig. 39, referred to *Polyptychodon rugosus*, and that represented in Figs. 45, 46, which I referred to a reptile of unknown relation with the name of *Drepanodon impar*, I also suspect to belong to *Mosasaurus*.

[1] Schädelbau des Mosasaurus. Nov. Act. Acad. C. L. C. Nat. Cur., Vol. XXI, p. 173.

[2] Ossem. Foss., Ed. 4, T. 10, p. 150.

[3] Ibid., p. 168.

[4] Ibid., p. 151.

[5] Ibid., p. 139.

[6] Ibid., p. 143.

[7] Ibid., p. 148.

[8] "Die vollständige Verknöcherung aller Theile, so wie die häufig bemerkbare Ausfüllung der Zähne beweisen, dass das Individuum seine vollständige Ausbildung erreicht hatte." Schädelbau des Mosasaurus, Nov. Act. Acad. C. L. C. Nat. Cur., Vol. XXI, p. 177.

[9] British Fossil Reptiles, p. 187.

[10] Ossem. Foss., T. 10, p. 165.

hypapophysis; thirty-eight without articular processes, but retaining transverse processes; twenty-six having the latter, and in addition, facets for chevron bones; forty-four without transverse processes, and possessing coossified chevron bones; and seven devoid of processes.

Goldfuss[1] estimates the number of vertebræ at about one hundred and fifty-seven, which he divides as follows: atlas and axis; thirteen vertebræ with a hypapophysis; twenty-six with transverse and articular processes, but no hypapophysis; thirty with transverse, but no articular processes; thirty as in the latter, but in addition, possessing chevron bones; forty-four without transverse processes, but having chevron bones; and twelve without processes.

The ribs articulated by their head alone with the ends of the transverse processes.

The most remarkable character in the anatomy of the vertebral column of the *Mosasaurus*, is the coossification, in the hinder part of the tail, of the chevron bones with the bodies of the vertebræ, a condition previously known only as a peculiarity of Fishes. The superior and inferior vertebral arches, in association with their long spinous processes, and the absence of transverse processes, indicate the tail of *Mosasaurus* to have presented the laterally compressed appearance and great vertical depth seen in many Fishes.

Another remarkable character is the absence, or rather the rudimental state, of the articular processes from about the middle of the vertebral series posteriorly, a condition likewise observed in Cetaceans.

The characters just given indicate *Mosasaurus* to have been eminently aquatic in habit. The tail possessed great freedom of movement in a lateral direction as in Fishes. The absence of articular processes in the posterior half of the vertebral series leads to the suspicion that no vertebræ were coossified so as to constitute a sacrum. Perhaps, also, there were no hinder extremities, though these may have existed, without the presence of a sacrum, adapted to swimming, as in *Plesiosaurus*, with which *Mosasaurus* exhibits other important points of resemblance, as will be seen hereafter.

Most of the remains of *Mosasaurus* which I have had the opportunity of examining have been derived from the Cretaceous Green-sand deposits of New Jersey, in which they are frequently found by those engaged in digging the Green-sand, or Marl as it is commonly called, for agricultural purposes. With the exception of a number of well-preserved teeth, the fossils have usually been submitted to me in such a fragmentary condition that they have served little else than to indicate the genus or family to which they belonged. I have seen no considerable portion of a skull, though I have met with small fragments of many skulls. Vertebræ, though common, are usually deprived of all their processes. Bones of the extremities are almost unknown.

The fossil remains of *Mosasaurus*, from New Jersey, are usually jet black, or iron-gray, more or less brittle, and impregnated with sulphuret of iron. Not unfrequently the pulp cavities of teeth and hollows of bones are occupied by solid accumulations of the latter substance. The decomposition of the sulphuret of iron,

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[1] Schädelbau, etc., Nov. Act. Acad., Vol. XXI, p. 194.

after the fossils are exposed to the air, renders them very liable to crack to pieces. Rarely I have seen remains of *Mosasaurus*, from New Jersey, of an ochre color and chalky consistence. Sometimes the fossils, but especially the teeth, are remarkably well preserved, and of very firm texture. Usually the enamel of the teeth is jet black and shining; occasionally gray, with brownish stains.

Besides the New Jersey specimens, I have seen a few others from the Cretaceous formations of the Upper Missouri, collected by Dr. F. V. Hayden, several from a deposit, of the same age, near Columbus, Mississippi, obtained by Dr. William Spillman, and one from near Marion, Alabama.

I have been unable to satisfy myself whether the specimens from the Upper Missouri, described by Dr. Goldfuss, and those submitted to my examination by Dr. Hayden, belong to the same species as the remains of the New Jersey *Mosasaurus.*

The specimens sent to me for inspection by Dr. Spillman consist of a basi-occipital bone, a tympanic bone, the greater portion of a pterygoid bone with teeth, a humerus, several vertebræ, and a few fragments of others. These were imbedded in a greenish sandstone, and apparently all belonged to the same individual, which I think was a different species, if not another genus, from the New Jersey *Mosasaurus.*

The museum of the Academy of Natural Sciences of Philadelphia contains thirty-two specimens of vertebræ of *Mosasaurus* from the Green-sand of New Jersey. They are chiefly from Burlington and Monmouth Counties, and were presented to the Academy by Mr. J. P. Wetherill, Dr. S. G. Morton, Dr. Charles T. Budd, Mr. T. Conrad, Dr. J. H. Slack, and Mr. L. T. Germain. The specimens belonged to a dozen or more individuals of different ages and sizes. All are much mutilated; one only retaining the vertebral arch. They consist of the following:—

1. A large cervical or anterior dorsal vertebra, represented in Fig. 1, Plate VII, from Monmouth County, N. J. The body measures three inches and a half from the bottom of the anterior concavity to the summit of the posterior convexity. The latter is sub-rotund, nearly as wide as high, measuring about two inches and two lines in diameter. The breadth of the specimen is six inches between the ends of the transverse processes, which are robust, conoidal, and project from the fore part of the body and abutment of the vertebral arch, obliquely backward, outward, and slightly downward. The spinal canal is obcordate, and about fourteen lines high and wide. The hypapophysis springs from a broad carina-like base, and is directed obliquely downward and backward. It is cylindrical, sixteen lines in transverse diameter, and truncated at the extremity, which is depressed at the centre into a conical pit.

2. A mutilated body of a cervical or anterior dorsal vertebra, from Burlington County, N. J. The body is two inches and a half long. Its posterior convexity is sub-circular, truncated above, and measures twenty lines wide and nineteen high. The hypapophysis is cylindrical, directed downward and slightly backward, and measures nine lines in transverse diameter.

3. Two bodies of cervical or anterior dorsal vertebræ, one of which is represented in Figs. 2, 3, Plate VII. The body is two inches and five lines long, but broader in relation with its height than in the preceding. The posterior convexity is reniform in outline, two inches wide and seventeen lines high. The cylindrical

hypapophysis, ten lines in diameter, projects from the middle of the body directly downward.

4. The body of a dorsal vertebra, not possessing a hypapophysis. Length three inches and a quarter; posterior convexity reniform in outline, thirty-one lines wide and twenty-one high. The remaining roots of the robust transverse processes spring from the body at its conjunction with the vertebral arch.

5. A series of three dorsal bodies, without hypapophysis, and measuring two inches and a half long. The roots of the transverse processes are situated at the middle of the sides of the body. The posterior convexity is reniform, thirty-two lines wide and twenty-three high.

6. A dorsal body with robust, conoidal transverse processes projecting from the forepart outward and backward. Length of body thirty lines; posterior convexity thirty lines wide, twenty-two high.

7. The body of a much mutilated dorsal vertebra, with the same form as the latter but larger.

8. Two bodies of lumbar vertebræ, with the remains of long, flattened transverse processes projecting outward and downward from the lower part of their sides. The posterior convexity is widest at its lower third, and narrows to the emarginate border of the spinal canal. Length of body in one specimen twenty-six lines, in the other twenty-three; greatest width of posterior convexity in both specimens thirty-one lines, height twenty-four lines. This form of vertebra is represented by Fig. 4, Plate 247, of the fourth edition of Cuvier's Ossemens Fossiles. The larger of the two specimens is represented in Figs. 9, 10, 11, Plate VII.

9. Five very much mutilated specimens of the same character as the preceding, but larger. From two different individuals and localities. The largest specimen is thirty-two lines long; the smallest twenty-six lines.

10. Five small vertebræ of the same form as the preceding, from several individuals and localities. The largest specimen is twenty-one lines long; the smallest eighteen lines. Two are represented in Figs. 12, 13, 14, Plate VII.

11. Four large caudal vertebræ with the same form of body, and with roots of transverse processes having the same form and position as in the preceding. In addition, roots of chevron bones project from the posterior inferior part of the bodies. The most perfect of the specimens has the length, width, and height equal, being thirty-nine lines in these different directions.

12. Two caudal bodies with lateral tubercles or mere rudiments of transverse processes; otherwise having the same form as the preceding, but smaller, their length being twenty-seven lines.

13. Three much mutilated caudals, relatively narrower than the former. The largest is twenty-eight lines long; the smallest twenty-four lines.

14. The body of a caudal vertebra, fourteen lines long.

Since writing the foregoing I have received, for examination, from Prof. Cook the following specimens:—

1. A dorsal vertebra, from Freehold, Monmouth County, N. J., loaned by Dr. C. Thompson. The specimen corresponds in form with a rather larger one previously described, and is represented in Fig. 8, Plate VII. It also bears considerable re-

semblance, both in form and size, with one of the specimens figured by Dr. Gibbes as characteristic of his *Amphorosteus Brumbyi.*[1]

2. The bodies of two large cervicals or anterior dorsals. The specimens, together with small fragments of a huge skull, were found in the first bed of Green-sand at Holmdale, Monmouth County, N. J. They are too much mutilated for detailed description, but are interesting on account of their size, as they measure a trifle over four inches in length. From their under part projects a robust, cylindroid hypapophysis, which, in both specimens, is broken at the extremity.

3. A specimen consisting of a pair of large posterior dorsals or lumbars, and part of a third with the bodies coossified by means of an irregular exostosis surrounding the articular surfaces. It belongs to Rutger's College, and though its locality is unknown, it is supposed by Prof. Cook to have been derived from the deepest layer of the Green-sand of Monmouth County, N. J. The anterior pair of vertebral bodies together measure seven inches in length; the anterior concave surface of the first body is about four inches in diameter, and the vertebral canal, retained entire, is transversely elliptical, and measures eleven lines wide and eight lines high.

From Nebraska Territory, the museum of the Academy of Natural Sciences has received a collection of remains of *Mosasaurus*, consisting chiefly of vertebræ, which were discovered by Dr. F. V. Hayden. The specimens are as follows:—

1. Several fragments of weather-worn rock, originally from the same mass, containing a series of sixteen caudal vertebræ, two others of small size detached from the series, and several bones of the extremities. The specimens were obtained on the Yellowstone River, and the bones all appear to have belonged to the same individual. The rock in which the fossils are imbedded bears some resemblance to that described by Dr. Goldfuss, as containing the *Mosasaurus* skeleton from the vicinity of the Big Bend of the Missouri River. It is a very hard, brittle, argillaceous limestone, amorphous, and of a dark, dull leaden hue. On the surface it has become softened, by the action of the weather, into a yellowish-gray material. The rock adheres so tenaciously to the equally brittle bones that they have been seriously injured in the attempt to expose them. The vertebræ, several of which are represented in Figs. 15, 16, Plate VII, present the anatomical characters ascribed to the posterior caudals of *Mosasaurus* by Cuvier, Goldfuss, and others. All had coossified chevron bones; and the anterior of the series have rudimental transverse processes, which entirely disappear in the more posterior ones. The body of the first of the series measures nineteen lines in length and twenty-three lines in height and width; that of the last is fourteen lines in length and twenty lines in height and width. The better preserved of the detached caudals, represented in Fig. 16, Plate VII, has its body only nine lines in length.

2. Two bodies of posterior caudals, well preserved, from Cheyenne River. They had coossified chevron bones and no trace of transverse processes. They measure fourteen lines in length, eighteen high, and nineteen wide. One of the specimens is represented in Figs. 17, 18, Plate VII.

3. Two caudal bodies, of the same form as the preceding, but rather larger, from

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[1] Mem. on Mosasaurus, Plate III, Figs. 14, 15, 16.

Little Moreau River, near Fort Pierre. The length of the more perfect is fifteen lines, the height twenty lines, and the width twenty-one lines.

4. A caudal body and a posterior dorsal body, from the forks of Cheyenne River. The former possesses rudimental transverse processes projecting from the middle of the sides, and measures eighteen lines in length, twenty-one in height, and twenty in width. The latter belonged to a very small species, comparatively, or to a very young individual of the larger species, but presents no indication of sutural attachment of parts. It measures fifteen lines in length, sixteen lines high, and nineteen lines wide.

5. A mutilated posterior dorsal body, and a mutilated anterior caudal body, from Little Moreau River, near Fort Pierre. The former had robust, transverse processes projecting from the middle of the sides of the body anteriorly. Its length is thirty-six lines, the height of its posterior convexity thirty-four lines, and its width thirty-three lines. The caudal had no chevron bones, but strong transverse processes projecting from the lower part of the sides of the body. The articular extremities in outline are triangular with strongly rounded angles. The length of the body is twenty-eight lines, the height of the posterior convexity about twenty-six lines, and the width below twenty-nine lines.

The vertebræ of *Mosasaurus*, previously mentioned as having been received from Dr. Spillman, who discovered them near Columbus, Mississippi, consist of two cervicals and the fragment of a dorsal.

The cervical vertebræ, represented in Figs. 4, 5, 6, Plate VII, have their body twenty-nine lines long, with a transversely oval posterior convexity twenty lines wide and sixteen lines high. The spinous process, long, strong, and laterally flattened, measures about two and a half inches along its anterior border. The spinal canal is about seven lines high and six lines wide. The transverse processes are of robust proportions and remarkable form. Springing from the conjunction of the vertebral arch and body, they form a rectangular protuberance, at first descending upon the side of the latter and then turning forward at a right angle to its anterior border. Their upper extremity is thick; and they narrow in their descent and anterior extension. Their free extremity presents an L shaped articular surface for a cervical rib. The hypapophysis is a strong process projecting downward from the back portion of the under side of the body; springing from a carina-like base it ends in an ovoid, truncated extremity, as seen in Fig. 4, Plate VII.

The fragment of a dorsal vertebra, represented in Fig. 7, Plate VII, has the body thirty lines in length, and in its details resembles the cervicals just described, except that its hypapophysis is a mere rudiment, indicating the position of the vertebra to be the next succeeding those anterior dorsals which possess a more distinctly developed process of the same character.

All the vertebræ which I have described or indicated, and indeed all the specimens I have seen, are apparently complete in their development, that is to say, none of them exhibit marks of original separation of the composite elements. The union of these in reptiles, especially the complete coossification of the vertebral arch and body, indicates maturity in the skeleton. Never having seen Mosasauroid vertebræ exhibiting certain signs of immaturity I have associated this negative evidence with the ichthyc character of the tail, and suspected that perhaps as in fishes, the vertebræ of *Mosasaurus* were developed from single centres of ossification. If such were the case, mere differences in size of corresponding vertebræ would not be sufficient to determine a difference of species.

From Prof. George H. Cook, of Rutger's College, New Brunswick, N. J., I have recently received, for examination, a number of remains of the *Mosasaurus*, from the Green-sand of Monmouth County, N. J. Among them is a collection, consisting of a multitude of small fragments of a skull, from the Marl digging on the farm of Isaac Smock, of Holmdale. The best preserved of the fragments consist of the greater part of both quadrate or tympanic bones, and the anterior extremity of the face or muzzle. The tympanic bones agree in form with the corresponding parts of those of the Maestricht skull preserved in the Paris museum. They measure about six inches in height, so that they are somewhat smaller than in the latter specimen.

The anterior extremity of the face, represented in Fig. 6, Plate XIX, consists of the forepart of the right maxillary bone, and nearly the entire intermaxillary bone. The end of the snout, as formed by the latter, is a demi-cone, with the flat surface comprising the forepart of the mouth. The height, breadth, and length of the demi-cone are nearly equal, being about three inches. The intermaxillary bone is prolonged upward and backward, and ends in a narrow process contributing to the partition of the anterior nares. It contains on each side of the palatine surface the fangs of two teeth, together with cavities for successors. It would thus appear that the number of intermaxillary teeth in *Mosasaurus* is one less on each side than supposed by Cuvier, though his numeration applied to the Maestricht *Mosasaurus*, in which species the number may have been greater than in the New Jersey Monitor.

In one respect the fossil appears to differ from the corresponding portion of the Upper Missouri skull, described by Dr. Goldfuss. In his, Plate 7, Vol. XXI, of the Nova Acta, representing a lateral view of the skull, the intermaxillary is not visible above the border of the maxillary bone, but is so in the New Jersey fossil, as seen in Fig. 6, Plate XIX of this memoir.

The forepart of the maxillary bone has lost the end which unites it with the alveolar border of the intermaxillary corresponding in extent to the position of the first maxillary tooth. Behind the latter the fossil contains the fangs of the four succeeding teeth. Accompanying the specimen are other fragments of the alveolar border, together measuring a foot in length, and occupied by the fangs of seven teeth, but not fitting from the loss of an intervening portion. About an inch above the alveolar edge there is a longitudinal row of large vasculo-neural foramina, which communicate with a canal situated along the outer part of the bottoms of the fangs of the teeth. Similar foramina form a row along the intermaxillary bone near its upper boundary. The anterior extremity of the nares, seen in the fossil, corresponds in position with the interval between the fifth and sixth maxillary teeth.

The length of the fossil, from the end of the snout to the posterior broken extremity, is ten and a half inches; the distance from the end of the snout to the anterior nares is ten inches.

Another collection, received from Prof. Cook, consists of fragments of the forepart of the lower jaw, obtained by Dr. C. Thompson from the Marl of Freehold, Monmouth County, N. J. Restored to their proper place the specimens correspond in size, shape, and number of insertions for teeth with the portion of a jaw of the Maestricht Monitor, figured in Plate VI, of the Historie de la Montagne de St. Pierre. The fragments compose twelve inches of the right dental bone, represented in Fig. 13, Plate XI, and sixteen of the left one. The latter presents a depth of four inches gradually decreasing to the anterior end where it measures about two inches. In their length the bones are remarkably straight, and their symphysial extremity, without arching inward, is obtusely rounded. The outer surface and base are convex. The former, half way between the latter and the alveolar border, exhibits a longitudinal series of large elliptical foramina directed obliquely forward and outward from the dental canal. Nearer the base approaching the symphysis, and also in the latter position, there exist a number of similar foramina. The left dental specimen has accommodated nine teeth, which are lost, except the fifth tooth and the fang of the first. The right dental specimen accommodated seven teeth, which are lost, except the fangs of the anterior three. The fangs and alveoli in the specimens are directed obliquely forward and upward with a feeble curvature. The angle of inclination of the fangs successively increases from behind forward. In the fifth tooth it is about 50°; in the first one about 30°.

The fifth tooth remaining in the left dental bone, has its crown mutilated, but a portion of the inner surface being preserved, exhibits a number of well-defined planes. The fang is about three inches in length, and exhibits a large excavation postero-internally for a successor.

In the right dental specimen the fang of the first tooth, two and a quarter inches long, presents a small concavity postero-internally, just below the alveolar border, for a successor. The fang of the second tooth is about one-third excavated, and the excavation at base impresses the front of the fang of the third tooth about its middle. Postero-internally the third fang presents a small excavation for its own successor.

Fig. 11, Plate VIII, represents a basi-sphenoid bone of *Mosasaurus*, from the first marl bed of Holmdale, Monmouth County, loaned to me by Prof. Cook. The specimen, a fragment of a huge skull, measures eight inches in length and six inches in breadth at the posterior diverging processes, which abut against the basi-occipital bone.

The basi-occipital bone, from Mississippi, part of the collection of Dr. Spillman, previously mentioned, is two inches long in the median line, and of ten lines greater width at the anterior diverging processes. The latter are separated by a wide concavity from each other and from the occipital condyle. They terminate in a reniform convexity; in front sustain the angularly divergent processes of the basi-sphenoid bone, and posteriorly support in part the lateral occipitals. The condyle, somewhat mutilated, in its entire condition has measured about two and a quarter inches in transverse diameter, and a little over an inch vertically. The portion contributed by the lateral occipital, preserved on one side in the fossil, is about three-fourths of an inch wide and half an inch high.

The tympanic bone, accompanying the former specimen, though much fractured, and partly imbedded in its matrix, is sufficiently well preserved to exhibit its true form. It presents considerable difference from that of the *Mosasaurus* of New Jersey, as it does also from that of the Maestricht skull of the Paris museum. It is of much greater breadth in proportion to its length, and is in comparison very abruptly narrowed at its lower part. Its height is three inches and a half, and its extreme breadth above is equal. The width of the mandibular articulation is one inch ten lines. The tympanic passage is proportionately larger, as is also the case with its posterior overhanging process.

The differences between this tympanic bone and that of the New Jersey, Missouri, or Maestricht *Mosasaurus* indicate the Mississippi *Mosasaurus* to be a distinct species.

Cuvier[1] observes, that very few bones of the extremities of *Mosasaurus* have been found, and their rarity was such that, for a moment, he was led to doubt whether the animal possessed limbs. He states that he was soon undeceived by recognizing a bone of the pelvis which certainly belonged to *Mosasaurus*. The bone, considered to be a pubis, resembling that of the Monitor, is figured in the Ossemens Fossiles. Cuvier further says, that among some fossils from Seichem he detected a scapula resembling that of the Monitor; and subsequently received drawings from Maestricht of a clavicle resembling that of a common Lizard, and also a coracoid bone. From the specimens and figures Cuvier supposes the shoulder of the *Mosasaurus* to have exhibited a close resemblance with that of the Lizards. After remarking that he had been unable to procure any long bones of the limbs of *Mosasaurus*, he expresses his views in regard to certain figures of bones, represented by Faujas-Saint-Fond[2] and Camper,[3] reproduced in the Ossemens Fossiles. In regard to the figure of a portion of an ulna, Cuvier observes, that if the bone belonged to *Mosasaurus*, it would indicate the extremities to have been moderately elevated. But he continues, the bones of the feet, so far as they are known, appear, on the contrary, to have belonged to a sort of contracted fin, as in the Dolphins or *Plesiosaurians*. Of the different bones of the feet, figured in the Ossemens Fossiles, after Camper, Cuvier likens some of them to the principal carpal bones of the Crocodile, another appeared to belong to some huge Saurian, some are phalanges, and two are attributed by him to Turtles, whose remains are not less common in the deposits containing those of the *Mosasaurus*. In conclusion, Cuvier adds that "it was not without hesitation that he expressed his conjectures from mere figures, when the immediate comparison of the bones themselves would scarcely suffice, so great is their diversity and so small the precision of their forms in reptiles."

Goldfuss[4] describes and figures several bone fragments from the deposits of the Cretaceous period of the Upper Missouri, which he views as the portion of a scapula, a coracoid bone, and an olecranon process of the *Mosasaurus*. In relation to the habits of the animal, he says, as it lived in the ocean the toes no doubt were

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[1] Ossemens Fossiles, Ed. 4, T. 10, pp. 170–173.

[2] Hist. Nat. de la Mont. de St. Pierre de Maestricht.

[3] Annales du Muséum, T. XIX.

[4] Schädelbau des Mosasaurus; Nov. Act. Acad. Caes. Leop. Carol. Nat. Cur., Vol. XXI, Pars 1, p. 173.

webbed, but the remains which have been discovered, on the contrary, do not lead to the supposition that it possessed fins like the *Ichthyosaurians*.[1]

Prof. Owen,[2] after remarking that no part of the organization of *Mosasaurus* is so little known as that of the locomotive extremities, and substantially quoting the views of Cuvier, expressed above, enters into the description of some long bones of the extremities, "showing the Lacertian type of structure," which were obtained in the Green-sand formation of New Jersey. Professor Owen observes, "on the highly probable supposition that these bones belong to *Mosasaurus*, they indicate the extremities of that gigantic Lizard to have been organized according to the type of the existing *Lacertilia* and not of the *Enaliosauria* or *Cetacea*."

Pictet[3] says the humerus of *Mosasaurus* is thick and short, like that of *Ichthyosaurus*, but gives no evidence for this assertion. He adds, we may conjecture, from the flattening of the bones of the members, that the feet were probably converted into fins like those of the *Enaliosaurians*.

Some remains, apparently of *Mosasaurus*, which I have the opportunity of examining, indicate the limbs to have been fins, partaking in their structure the characters of those of the marine Turtle and the *Plesiosaurus*.

The humerus previously mentioned, found in association with several cervical vertebræ, a tympanic bone, and a pterygoid with teeth, submitted to my inspection by Dr. Spillman, of Mississippi, is represented in Figs. 1, 2, Plate VIII. Having every appearance of belonging to the same skeleton as its associated bones, there can be but little doubt of its appertaining to *Mosasaurus* or one of its allies.

The specimen is of the right side, and bears a striking resemblance to the humerus of a Turtle, with which I suppose it to have corresponded in the relative position of its parts, and shall, therefore, so describe it.

The shaft is short and rapidly expanded towards the extremities. Its middle part is cylindrical, but much compressed antero-posteriorly. The borders form a deep curve in the length, and are transversely convex, but the outer is the more obtuse. The posterior surface, Fig. 1, is transversely convex; the anterior, Fig. 2, nearly flat, and marked just above the middle by a roughness (*d*) for muscular attachment.

The proximal extremity expands to more than three times the breadth of the middle of the shaft. A demi-spheroidal head (*a*) projects forward, midway between two tuberosities, and is partially sustained in the usual manner by a gradual uprising abutment of the shaft. The tuberosities include a deep concavity back of the head, and are associated by the posterior terminal portion of the shaft, which presents a broad and slightly concave surface extending between them. The greater tuberosity (*b*), situated postero-superiorly, extends a short distance proximally beyond the head so as to increase the length of the bone. It is compressed antero-posteriorly, and, in the specimen, is imperfect at the summit. The lesser tuberosity (*c*), situated

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[1] Op. cit., p. 196. Da sie sich im Meerwasser aufhielten, so waren die Zehen ihrer Füsse ohne Zweifel mit Schwimmhäuten verbunden; die gefundenen Knochenreste lassen dagegen nicht vermuthen, dass die Flossenfüsse, wie die Fischeidechsen gehabt hatten.

[2] British Fossil Reptiles, p. 190

[3] Traité de Paléontologie, Ed. 2, T. 1, p. 505.

postero-inferiorly, is thicker than the former, and exhibits strong marks for muscular attachment.

The distal extremity of the bone expands to about twice the breadth of the middle of the shaft. It is almost flat in front, moderately convex behind, and terminates in a thick angular border, which, though somewhat mutilated, has the appearance as if it had formed a fixed or immovable joint with the bones of the forearm. The measurements of the specimen are as follows:—

	Inches.	Lines.
Extreme length of the specimen in its present state	10	
Breadth of shaft at middle	1	11
Thickness of shaft at middle	1	2
Breadth at tuberosities, estimated	6	
Diameter of head	1	8
Breadth at distal end	3	8
Thickness at distal end	1	2

A fragment of a huge bone, from the Green-sand of Burlington County, N. J., contained in the cabinet of the Academy of Natural Sciences, is represented in Figs. 3, 4, 5, Plate VIII, rather less than one-third the diameter of the original. The specimen has been usually viewed as the proximal extremity of the humerus of an enormous Turtle, and even Agassiz was impressed with the same idea, for it is the fossil characteristic of his *Atlantochelys Mortoni.*[1] It bears a resemblance to the corresponding portion of the humerus just described, and probably belongs to the gigantic *Mosasaurus.*

The shaft, broken across near its middle, appears of exceeding narrowness in comparison with the breadth of the bone at the tuberosities, and, indeed, is much narrower in this respect, relatively, than in the humerus above described. From this character alone we have good reason to suspect that the two specimens indicate a small and a large species of *Mosasaurus.*

The broken end of the bone, under immediate examination, presents an ovoidal section, with the greater diameter thirty-four lines, the shorter twenty-nine lines. The shaft contains no medullary cavity, but is occupied by an interior coarser ossific structure. The upper or front part of the shaft, as in the preceding specimen, exhibits a rough, tuberous surface for muscular attachment.

The head is ovoidal in outline, fifty-three lines in its antero-posterior diameter, and forty-four lines in its short diameter.

The breadth of the bone, from the summit of one tuberosity to that of the other, is eleven inches. The greater tuberosity projects three inches proximally beyond the head, increasing by so much the length of the bone. It is compressed antero-posteriorly, is convex and rough at the summit; measures four inches wide at its middle, and twenty-six lines thick. The smaller tuberosity, irregular in form and much roughened for muscular attachment, measures forty-one lines in thickness.

The length of the fragment, from the summit of the greater tuberosity to the broken end of the shaft, is eleven inches.

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[1] Proc. Acad. Nat. Sci. 1849, 169.

The mass of hard blue stone, previously noticed, containing a number of caudal vertebræ in a row, obtained by Dr. Hayden on the Yellowstone River, also contains a broad bone, represented in Fig. 12, Plate XVII, together with several small bones, like that represented in Fig. 13, of the same Plate, all of which appear to have belonged to the same skeleton.

The broad bone is yet partially imbedded in its hard matrix, the removal of which would endanger the integrity of the specimen. It resembles in general form the ulna or fibula of *Plesiosaurus*, and from its being found with caudal vertebræ might be suspected to be the latter bone. It is not, however, unlikely that it may prove to be a tarsal bone, one of which it likewise resembles in the foot of *Plesiosaurus*. It is about as broad as it is long, and the exposed surface exhibits a radiate ossific structure. Internally the upper part of this surface is transversely convex, but is slightly depressed below; externally it is concave. The upper border is convex in the direction of the breadth of the bone. The inner border is longitudinally concave, transversely convex, thick, and smooth. The outer border is thin, emarginate, and presents an irregular pitted appearance as if it had been covered with cartilage. The lower border at its inner third forms an obtuse angle, is thick, and subdivided into a pair of concave articular facets. The measurements of the bone are as follows:—

	Inches.	Lines.
Extreme length	3	2
Breadth above	2	10
Breadth at the middle	2	4
Breadth below	3	2
Thickness at the lower border	1	2
Thickness at the outer border		4

The small bones above alluded to appear to be metatarsals and phalanges; and they closely resemble the corresponding bones of the *Plesiosaurus*. One of the best specimens, represented in Fig. 13, Plate XVII, has a quadrate shaft strongly expanded at the extremities. The proximal end is the larger, and presents a transversely oval, flat articular surface. The distal articular surface is likewise oval, but is concave. The measurements of the specimen are as follows:—

	Lines.
Length	22
Breadth of proximal end	14
Thickness of proximal end	7
Breadth of middle of shaft	5
Thickness of middle of shaft	4
Breadth of distal end	12
Thickness of distal end	7

Two additional specimens, partially imbedded in their matrix, present very nearly the same form and size as that just described.

Other bones of the limbs, which may, with the same probability as the preceding, be referred to *Mosasaurus*, I have not had the opportunity of examining.

An isolated bone, somewhat crushed in appearance, belonging to the cabinet of Prof. James Hall, and obtained by Messrs. Meek and Hayden, from the Cretaceous deposits of Nebraska, is represented in Fig. 6, Plate VIII, and may, perhaps, appertain to a young *Mosasaurus*. It resembles a radius or tibia of *Plesiosaurus*. It is much compressed, cylindroid in form, and expanded nearly equally towards the extremities. The articular surfaces are transversely elliptical, slightly convex, and roughened for the attachment of cartilage. The measurements of the specimen are as follows:—

	Inches.	Lines.
Length	2	8
Breadth at middle of shaft	1	1
Thickness at middle of shaft		6
Breadth at extremities	1	8
Thickness		9

An isolated bone, obtained by Dr. Spillman, from the same formation, which contained the humerus and other bones previously described, is represented in Fig. 7, Plate VIII. It resembles the preceding specimen suspected to be a radius or tibia of a young *Mosasaurus*, but is much less compressed, and its articular surfaces are nearly plane or slightly concave. Its measurements are as follows:—

	Inches.	Lines.
Length	2	
Breadth at middle of shaft		9
Thickness at middle of shaft		7
Breadth of proximal end	1	6
Thickness of proximal end	1	
Breadth of distal end	1	4
Thickness of distal end		10

A carpal bone, represented in Fig. 8, Plate VIII, found by Dr. Hayden on the Big Cheyenne River, probably belongs to *Mosasaurus*. The specimen is hexagonal at the border, and has its broad surfaces moderately concave. Its greatest breadth is one inch, its shortest ten lines; its thickness ranges between three and five lines.

An undetermined reptile bone, accompanying the latter, is represented in Fig. 10, of the same Plate. It is a short, much flattened, cylindroid bone, constricted at the middle, where it measures one inch and a quarter wide, and three-quarters of an inch thick. The upper extremity expands into a broad, flat, circular articular surface, with a narrow oblique prolongation at one side. The surface is broken off at the opposite side, but independent of the prolongation it measures about one inch and a quarter in diameter. The lower extremity expands into a transversely semi-circular, ellipsoidal articular surface, measuring two inches and three-quarters in its long diameter and ten lines in its short diameter. The length of the bone is one inch and three-quarters.

Another undetermined reptile bone, represented in Fig. 9, Plate VIII, belonging to Prof. James Hall, was found by Messrs. Meek and Hayden, among loose fragments at the base of a Cretaceous bluff, five miles below Daurion's Hill, Nebraska. The bone is a little over two inches in length, and somewhat resembles the preceding, but appears lengthened at the expense of the breadth. The shaft at middle is eleven lines wide and eight lines thick, and is ovate in transverse section. The upper extremity expands into a flat, nearly circular articular surface, about one inch and a quarter in transverse diameter, and a little less in the opposite diameter. The lower end of the bone expands transversely, and ends in a long, curved ellipsoid surface, apparently subdivided to articulate with three carpal bones. The length of this surface transversely is two inches and a quarter, its breadth three-quarters of an inch.

Specimens of isolated teeth, possessing the general characters assigned to those of the Maestricht Monitor or *Mosasaurus*, but exhibiting considerable diversity of size and form, are frequently discovered in the deposits of the Cretaceous period of the United States. A number of such teeth are contained in the cabinet of the Academy of Natural Sciences, and others have been loaned to me for examination, but I find it difficult to decide whether they belong to one or more species of the genus or to several distinct genera. In attempting to determine the limit of variation in the form of the teeth of *Mosasaurus*, I have greatly felt the want of a careful description in detail, accompanied by accurate figures, of the fine specimen of the jaws and teeth, upon which the genus was founded, and which is now preserved in the museum of the Jardin des Plantes, at Paris. I have had access to an excellent plaster cast of the specimen presented by the Directors of the latter institution to the American Philosophical Society, but in many respects it fails to show nice shades of character, which are, no doubt, to be observed in the original, or which might be the subject of description and accurate delineation. The descriptions and figures by Faujas-Saint-Fond, Cuvier, and others, though sufficiently characteristic of the genus, and mainly correct, are not given with the detail and precision that are required for comparison of the specimens I have the opportunity of examining.

Cuvier[1] briefly describes the teeth of *Mosasaurus* in general. He observes, that they are all pyramidal and slightly curved; their external face is plane, and defined by two acute ridges from the internal face, which is round, or rather demi-conical. Subsequently[2] he remarks, that the ridges are entire and without denticulations. He does not refer to the existence of divisional planes upon the teeth; and an inspection of undoubted teeth of the genus leaves no question that the ridges of the crown are minutely denticulate in the unworn condition. An examination of the cast, above mentioned, also proves that there is some diversity in the shape of the teeth in different parts of the series.

Goldfuss,[3] in describing the teeth of *Mosasaurus*, says they are slightly compressed laterally, towards the apex feebly curved backwards, and are divided into a larger inner and smaller outer half by an acute linear ridge, which is transversely striated. Their surface appears polygonal; the outer surface presenting five, the inner seven pyramidal planes. Prof. Owen,[4] in referring to the description of Goldfuss, remarks, "the feeble indications of angles observable in some of the teeth, those of the upper jaw chiefly, of the *Mosasaurus Hoffmanni*, do not bear out the term 'polygonal,' which he applies to the crowns of that species as well as to those of his *Mosasaurus Maximiliani;* still less can I find these angles so constant and regular as to

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[1] Ossemens Fossiles, Ed. 4, T. X, p. 144.

[2] Ibid., p. 145.

[3] Schädelbau des Mosasaurus; Nov. Act. Acad. C. L. C. Nat. Cur., Vol. 21, p. 178.

[4] British Fossil Reptiles, p. 185.

divide the outer surface of the crown into five, and the inner surface into seven facets."

The plaster cast, above mentioned, of the jaws of the Maestricht Monitor, shows that the front teeth are narrower than those behind. The external surface of the crown is comparatively narrow and slightly convex, while the internal surface is of considerable extent, forming in section the transverse half of an ellipsoid. In passing backward in the dental series it appears that the external surface of the crowns increases in breadth and becomes more convex, while the internal surface in a corresponding manner decreases. In the back teeth the crown appears to be laterally compressed conical, with the external surface nearly as wide and convex as the internal, so that a transverse section presents an ellipse with acute poles. Thus the front teeth of the cast correspond with those usually described as characteristic of *Mosasaurus*, while the back ones are more like those supposed by Prof. Owen to indicate a distinct genus, which he has named *Leiodon*.

In most of the teeth, usually assigned to *Mosasaurus*, the inner and outer surfaces of the crown are more or less distinctly subdivided into a series of narrow planes, which are most evident towards the base of the crown. These planes are variable in number, and are often slightly depressed or feebly concave. They are sometimes multiplied towards the base, but become indistinct or even disappear at the summit. In the plaster cast the divisional planes of the surfaces of the crown, while sufficiently evident in the more anterior teeth, appear to be obsolete in those most posterior, though it is true that their absence in the latter may arise from defective modelling.

In the Maestricht Monitor, Cuvier[1] observes that, "the teeth are hollow only during their development, as they are then in all other animals. They become filled throughout their length, and are most frequently found entirely solid. They complete their development in becoming attached to the jaw by means of an osseous body very different in structure from that of the tooth, with which it is nevertheless intimately associated. The successional tooth originates in a special alveolus produced at the same time, and it penetrates the osseous body of the tooth in use. In enlarging the successional tooth finally detaches the osseous body from the jaw with which it was organically united; the body by a sort of necrosis being shed and carrying with it the tooth it supported. Gradually the successional tooth, with its body, improperly called its osseous root, assumes the position from which the old one was removed."

Subsequently, Cuvier,[2] after remarking that "he had formerly committed the error of calling the osseous structure, connecting the tooth with the jaw, the root," observes that "he had since recognized it to be the dental pulp, which, instead of remaining soft as in mammals, becomes ossified and identified with the alveolus." Cuvier continues, "the tooth has no true root, but adheres strongly to the pulp which secreted it, and is further held in connection with it by the remains of the capsule which furnished the enamel, and which, by becoming ossified also, and

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[1] Ossemens Fossiles, Ed. 4, T. 10, p. 134.

[2] Ossemens Fossiles, 136.

uniting itself with the maxillary bone and the ossified dental pulp, inserts and fixes the tooth with additional force."

Again, in comparing the mode of implantation of the teeth of *Mosasaurus* with the living *Monitor* and *Iguana*, Cuvier[1] observes of the former that "the socles (pedestals) or ossified pulps, which support the teeth, are adherent in hollows or true alveoli contrived in the thickness of the border of the jaw."

Goldfuss,[2] referring to the Maestricht and the Missouri *Mosasaurus*, says, "in both, the crowns of the teeth, invested with shining enamel, are sustained upon the dental capsule which is transformed into an osseous socle, coossified with the alveolus, and they are in part hollow internally and in part solid."

Owen, in his Odontography, page 258, in reference to *Mosasaurus*, observes that "the maxillary teeth combine the pleodont with the acrodont characters." Further on he continues, "its dentition exhibits in an eminent degree the acrodont character; the teeth being supported on expanded conical bases anchylosed to the summit of the alveolar ridge of the jaws; no existing Saurian exactly parallels this mode of attachment of the teeth, either in regard to the breadth of the alveolar border or in the relative size of the osseous cones to the teeth which they support. A shallow socket is left where the tooth and its supporting base are shed." The same authority, in a more recent work, Palæontology, page 279, remarks that "the teeth are anchylosed to eminences along the alveolar border of the jaw according to the acrodont type."

Pictet, in his Traité de Paléontologie, tome 1, page 504, speaks of the teeth of *Mosasaurus* as being deprived of true roots and anchylosed to the jaw.

Gibbes, in his Memoir on the Mosasaurus,[3] follows the descriptions of Cuvier and Owen.

Gervais, in the Zoologie et Paléontologie Françaises, tome 1, page 262, in describing some teeth which he refers to *Leiodon*, observes that as in *Mosasaurus* they are inserted in alveoli with which their root is identified by means of the surrounding layer of cement. In a note he adds the remark, "c'est a tort que l'on décrit les dents des *Mosasaures* comme réellement acrodont a la maniere de celles de beaucoup de Sauriens actuels."

From the fossil specimens I have had the opportunity of examining, the history of the dentition of *Mosasaurus*, so far as I have been able to trace it from the imperfect materials, appears to be as follows:—

The mature teeth of *Mosasaurus* have curved conical crowns with long, robust fangs inserted into sockets or alveoli, with which they were at first connected in the ordinary manner by connective tissue, but with which they subsequently became firmly coossified.[4] They contain in the interior a large fusiform pulp cavity com-

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[1] Ossemens Fossiles, 143.

[2] Schädelbau des Mosasaurus; Nov. Act. Acad. C. L. C. Nat. Cur., XXI, 178. Bei beiden sitzen die, mit einem braunen, glänzenden Schmelze überzogenen Zahnkronen auf der zu einen verknöcherten Sockel umgewandelten, in der Alveole angewachsenen Zahnkapsel, und wird im Innern theils hohl, theils ausgefüllt.

[3] Smithsonian Contributions, Vol. II.

[4] Goldfuss (Nov. Act. Acad., XXI, Pl. 9) has given two figures of teeth with their fangs, which

municating through a canal with a funnel-shaped pit at the end of the fang. See Plates IX, X, XI.

The conical crowns of the teeth are curved backward with an inclination inward; the curvature being more rapid approaching the apex. They are generally divided in front and behind by an acute ridge into an inner and an outer surface. In some teeth, apparently belonging to the most posterior of the dental series of the jaws, and to those of the pterygoid bones, there is only one ridge, which is situated along the back or concave border of the crown. The ridges exhibit a minutely crimped and sub-denticulated arrangement,[1] which was obliterated by wearing.

The proportionate extent of the inner and outer surfaces of the crown, as defined by the two ridges above indicated, varies very much in the different specimens of fossil teeth, apparently according to the position the latter occupied in the dental series.

In those teeth, which I suspect to belong to the anterior part of the dental series, the crown has the form corresponding with the descriptions which have usually been given as characteristic in general of the teeth of *Mosasaurus* (Plate IX, Figs. 1, 2, 3; Plate X, Figs. 1, 2, 3). It is very unequally divided by the acute ridges; the inner surface occupying two-thirds or more of the extent of the crown. The convexity or transverse curvature of the outer surface forms a short segment of a comparatively large circle; that of the inner surface forms one-half to two-thirds or more of a circle, whose diameter is that of the crown. The transverse section of the crown might be appropriately called shield-shaped, as represented in the woodcut outlines, Nos. 1, 2, 3.

In those teeth which are supposed to belong to the middle of the dental series the disproportion between the outer and inner surfaces of the crown is comparatively trifling, and the transverse section is circular or nearly so (Plate IX, Figs. 5, 6; Plate X, Figs. 7-9).

Teeth attributed to the more posterior part of the dental series have their crowns compressed from within outwardly and nearly equally divided by the acute ridges, and in transverse section are elliptical with acute poles (Plate X, Fig. 10).

Finally, the last teeth of the series have compressed crowns, with a single ridge, and an ovate transverse section (Plate X, Fig. 4).

The inner and outer surfaces of the crowns in most of the fossil teeth are unequally subdivided into narrow planes, variable in number. They slightly multiply towards the base of the crown, and become fewer and less distinct, or altogether disappear towards the apex. They vary in degree of distinctness in different teeth, and in many do not exist at all (Plates IX, X, XI).

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he indicates as a maxillary and a palatal tooth of *Mosasaurus Hoffmanni*. The tooth represented in his figure 4 looks as if it may have belonged to near the middle of the dental series. The inner side of its fang exhibits a small lenticular excavation; part of the receptacle of a successional tooth. Fig. 5, represented as a palatal or pterygoid tooth, I suspect rather to belong to the back part of the maxillary series. The two figures are reproduced by Gibbes in Plate I, of his Memoir on the Mosasaurus.

[1] This arrangement appears not to have been noticed by Cuvier in the teeth of the Maestricht Monitor. Ossemens Fossiles, T. X, 145.

The fossil teeth under examination would appear to indicate that the subdivision of the inner and outer surfaces of the crown is best marked in the anterior teeth of the series, becomes less evident in passing backward, and ceases in the last teeth. Some of the specimens would appear to show that the subdivision of the crown held some relation with the age of the animal; not existing in the young, but developed in the mature animal. Other specimens appear to indicate that the difference was due to individual peculiarity, or perhaps in some it may denote a difference of species if not of genus.

The fangs of the teeth of *Mosasaurus* are remarkable for their great proportionate size, being several times the bulk of the crown they support (Plate IX, Figs. 1–7; Plate X, Figs. 1, 2, 4, 7, 8, 10).

From the enamel border of the base of the crown the fang expands in the form of a cone to the entrance of its socket, where it presents its greatest diameter and is more or less defined by a shoulder or ledge (Plate IX, Figs. 1, 5; Plate X, Figs. 7, 8, 10; Plate XI, Figs. 1–6).

The intra-alveolar portion of the fang, from two to four times the length of the extra-alveolar portion, is straight, oblique, or slightly curved, cylindroid, and slightly narrowed towards the obtusely rounded end. Frequently it is more or less compressed from without inwardly; and occasionally wrinkled at bottom.

The mature fang was at first simply inserted about three-fourths or more of its length in its socket, with which it was evidently adherent in the ordinary manner by connective tissue. Subsequently, however, it became firmly coossified with the alveolus; the ledge or base of the extra-alveolar portion with the entrance of the alveolus at the border of the jaw; the intra-alveolar portion with the sides and bottom of the alveolus.

The pulp cavity (Plate IX, Fig. 6, *f;* Plate XX, Fig. 3, *c*) of the mature teeth of *Mosasaurus* occupies a large extent of space in their interior. It is fusiform, or doubly conical, one cone extending into the crown, the other into the fang. It communicates by a large canal with a funnel-shaped pit, usually more or less compressed, at the bottom of the fang.[1] Occasionally the canal is occupied by a coarse cementum pervaded by many large vasculo-neural canals, as represented in the diagram, Fig. 3, *d*, Plate XX.

The crown of the teeth of *Mosasaurus* (Fig. 3, *a*, Plate XX) is composed of compact dentine invested with a thin layer of enamel. At the base of the enamelled crown the dentine extends, in the form of an inverted cone, within the extra-alveolar portion of the fang and terminates in a thin, abrupt annular margin, encircling the pulp cavity, as represented in the diagram, Fig. 3, *e*, Plate XX.

The dentine, as represented in Figs. 4, 5, 6, *a*, Plate XX, presents the ordinary constitution of an amorphous substance, pervaded with innumerable canaliculi diverging from the pulp cavity to the periphery of the crown, dividing in their course and giving off multitudes of lateral anastomosing branches. Below the

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[1] Owen says, "The pulp cavity generally remains open at the middle of the base of the crown of the tooth; irregular processes of the cavity extend as medullary canals into the conical base of the tooth." Odontography, 259.

enamel border of the crown the dentine is defined from the cementum of the extra-alveolar portion of the fang by a more amorphous bond of union of the two structures, as indicated by the clear dividing line in the figures above mentioned.

The fang (Fig. 3, *b*, Plate XX) is composed of cementum or bone, as represented in Fig. 4, 5, 6, *b*, of the same plate. It is mainly composed of vertical osseous fibres, pervaded by numerous vascular canals pursuing the same course as the former. It is of much finer texture than the bone of the jaw with which it may be intimately coossified, and is admirably adapted to sustain the crowns of the teeth, both as regards its organic and its physical functions.[1]

The teeth of *Mosasaurus*, belonging to the functional series or those in use, were succeeded by a new set which underwent their development at the postero-internal portion of the alveoli occupied by the former. For the reception of the growing crowns of the new teeth the fangs of the functional series were gradually excavated through absorption of their structure, in a direction from within obliquely outward and forward, upward and downward. At first the inner parapet of the jaw slightly contributed to the parietes of the cavity for the new tooth, but, with this trifling exception, it was through excavation of the contiguous fang of the functional tooth that the former was accommodated. In the progress of the excavation, the pulp cavity of the functional tooth became exposed and then cut off from communication with the nerves and bloodvessels which supplied its contained pulp. The fossil specimens further indicate that it was during the progress of the excavation of the fangs of the functional teeth that these became coossified with their alveoli, as if to resist a tendency to expulsion from the jaw.

The cavities for the new teeth, in the fossils, are ovoid in form, and open at the postero-internal part of the extra-alveolar portion of the base of the fangs of the functional teeth; and from the opening the apex of the new tooth is seen protruding.

After the development of the crown of the new tooth the fang was produced, and the increase gradually became so great at the next step as to have converted the fang of the old tooth into a large capsule, surmounted by its crown still in use. With the advance of growth of the new tooth the crown of the old one became so enfeebled in its connection with its excavated fang as readily to be broken off by external violence, or to be displaced by the continued growth of the fang and protrusion of the crown of the new tooth. The fang of the latter continued its growth within a mere cylinder of the fang of the old tooth until its crown was made to assume a position in the functional series.

The development of the new tooth was scarcely completed before a successor commenced the same process, and thus one tooth was followed by another throughout the life of the animal, as in recent Reptiles (Plate IX, Figs. 1, 4, 5, 6; Plate X, Figs. 1, 4, 7, 8, 10; Plate XI, Figs. 4, 5, 6, 8, 10).

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[1] Owen says, "The expanded base of the tooth," referring to what has been mentioned above as the extra-alveolar portion of the fang, "is composed of a mere irregular mass of dentine, which, by its progressive subdivisions into vertical columnar processes, assumes a structure resembling that of true bone." Odontography, 259.

Some of the fossil specimens show that not unfrequently, while a successional tooth occupied a cavity within the fang of its predecessor, it was accompanied by another, situated behind the former. For the accommodation of the second successor a cavity was produced, not only at the expense of the fang occupied by the first one, but partly at the expense of the alveolar partition and fore part of the fang of the functional tooth behind. Figs. 1, *c*, 10, *c*, Plate X, and Figs. 5, *e*, 6, *e*, Plate IX, exhibit successive stages in the production of a cavity for a contemporaneous second successional tooth. The large cavity, represented in the last figure, is evidently compounded of two.

The pulp cavity of the teeth of *Mosasaurus* varied in size according to the period of development and age of the teeth, but all the fossil specimens I have seen indicate that it was absent at no period. I have never seen a solid tooth of the American *Mosasaurus*, contrary to the statement of Cuvier, in regard to the Maestricht Monitor, that the teeth are only hollow during their development, and are most frequently found entirely solid.[1] Nor does the large size of the pulp cavity in the mature teeth warrant the term of pleodont applied to the *Mosasaurus* by Owen.[2]

In the shedding of the crowns of the teeth of *Mosasaurus* they appear generally to have been detached from their excavated fangs a couple of lines from the enamel border. In several fossil specimens the base of the shed crowns is excavated in a conical or lenticular manner from the periphery to the central remnant of the pulp cavity. The peripheral border varies from a thin sharp edge to a fractured one of a couple of lines in thickness. The remnant of the pulp cavity, where it communicates with the excavation, is about a third of the diameter of the crown, and from one-third to one-half its length.

The alveoli generally appear to be completely separated in the ordinary manner among most animals by thin osseous partitions. In those instances in which there were two nearly contemporaneous successors to a tooth in use, the crowding to accommodate the former appears to have been such that the alveolar partition was obliterated, and was subsequently replaced by the cylindrical remains of the fangs which were excavated for the successional teeth.

The fossil specimens I have had the opportunity of examining, illustrating the dentition of *Mosasaurus*, are as follows:—

1. An alveolar fragment, containing a mutilated tooth and the fang of a second, from Burlington County, New Jersey, belonging to the museum of the Academy of Natural Sciences. It indicates an individual as large as that to which belonged the great skull of the Maestricht *Mosasaurus*, preserved in the museum of the Jardin des Plantes of Paris; and the mutilated tooth it contains resembles in its form those in advance of the middle of the series in the plaster cast of the skull just mentioned. An inner view of the specimen is given in Fig. 1, Plate IX. The fragment is from the right side of the upper jaw, and measures about eight inches in length by three inches in thickness. The external surface is straight longitudinally and convex vertically. About half way between the alveolar edge and the broken border, a distance of about three inches, it presents a transverse row of large vasculo-neural

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[1] Ossemens Fossiles, Ed. 4, T. 10, p. 134.

[2] Odontography, 258.

foramina, which communicate with a narrow canal situated just externally to the bottom of the fangs of the teeth.

The mutilated tooth of the specimen (Fig. 1, *a*) has a large portion of the crown destroyed, especially at its outer part, but it has been artificially restored in such a manner as sufficiently well to exhibit its original form.

This agrees with the ordinary descriptions characterizing the teeth of *Mosasaurus.* It is conical, curving moderately backward and inward, and in its perfect condition has measured about two inches and a half in length. The diameter at the enamelled base has been about fourteen lines, both antero-posteriorly and transversely. The transverse section is shield-shaped, as represented in the wood-cut outlines, Nos. 1, 2, 3, of more perfect specimens of teeth. A pair of acute, feebly denticulated, crimped ridges divide the crown irregularly into two surfaces, of which the outer is about one-half the extent of the inner. The transverse curve of the outer surface forms a short segment of a comparatively large circle, and measures at the bottom of the crown fifteen lines; the curve of the inner surface forms half an ellipse, and measures twenty-nine lines. Both surfaces have been subdivided into narrow planes; the outer exhibiting traces of three or four; the inner presents eight, of which the extreme ones are twice the width of those intermediate.

The fang (Fig. 1, *b*) is three inches and three-quarters in length, and is exserted about one-fourth; the base of the extra-alveolar portion measuring an inch and three-fourths in diameter. The intra-alveolar portion is firmly coossified with its alveolus, and is about one-half excavated postero-internally for the accommodation of a successional tooth. The cavity, from which the latter has been lost, is open at the postero-internal portion of the alveolar border, as represented in Fig. 1, *d*, and is also exposed by the destruction of the thin bottom of the alveolus, as seen in the same figure at *c*. Notwithstanding the extent of the excavation of the fang, the pulp cavity of this tooth is not exposed, except through a narrow aperture remaining from the canal of communication with the bottom of the fang.

The next succeeding fang of the fossil (Fig. 1, *f*) is like that just described, except that the cavity for a successional tooth is comparatively small. It is seen in the figure at *h*, opening at the border of the jaw postero-internally. It is oval, about sixteen lines in depth, and eight lines in breadth. The end of the fang is seen, as represented in the figure at *g*, through the open bottom of the alveolus. The canal, which usually communicates through the fang with the pulp cavity, is filled up with coarse cementum. At the summit of the extra-alveolar portion of the fang, from the loss of the crown, the bottom of the pulp cavity of the latter is exposed. The aperture is obliquely oval, and measures nine lines in the long diameter and six in the short diameter. From the aperture the cavity extends into the fang, in the form of a cone, an inch and a half in depth.

Behind the fang just described, the fossil retains one-half of an alveolus, which is interesting, from its exhibiting a thin plate of bone, as seen in Fig. 1, *i*, the remains of the fang which once occupied it. The plate is coossified with the alveolus, and formed part of the wall of the cavity of a successional tooth which is lost.

2. A fragment, apparently from the forepart of the lower jaw, containing the fangs of four teeth, from Burlington County, New Jersey, presented to the Academy of Natural Sciences by Dr. S. G. Morton. The fragment is ten inches long, and was sufficient to accommodate six teeth. At its widest part, opposite the position of the fifth tooth from the anterior extremity, it measures two inches and a half. The inner and outer surfaces are straight longitudinally and convex vertically. The outer surface, about an inch and a half from the alveolar edge, and near the broken border of the specimen, presents a transverse row of four large vasculo-neural foramina, communicating with the remains of the dental canal within.

The four fangs of teeth, contained in the specimen, are about three inches in length, of which about three-fourths are inserted within alveoli. The exserted or extra-alveolar portions of the fangs form truncated cones at the border of the jaw surmounted by the fractured borders of the lost crowns. The loss of the latter has exposed the base of the large interior pulp cavities, which measure from half to three-fourths of an inch in diameter and extend in an inverted conical manner within the fangs.

At the border of the jaw, the bases of the extra-alveolar portions of the fangs range in transverse diameter from fourteen to twenty-two lines.

The intra-alveolar portions of the fangs are cylindroid, moderately curved, and terminate in rounded extremities just internal to the position of the dental canal.

The first and third fangs of the specimen are loosely inserted in their sockets, with which they appear never to have been coossified. The second and fourth fangs are firmly coossified with their alveoli, and are deeply excavated postero-internally into large cavities which accommodated successional teeth, but which are lost from the specimen.

The second, third, and fourth fangs are separated by thin osseous partitions of the alveoli.

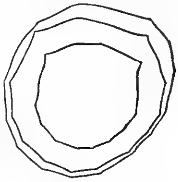
The fourth fang presents in its postero-internal part a small cavity for a successional tooth.

The first fang encroached so much on the position of the second as to have depressed its anterior part. It presents the remains of a very small cavity for a successional tooth in the same position as the other fangs, and exhibits what appears to be a portion of a second and larger one at the forepart.

3. A tooth, from Monmouth County, New Jersey, loaned to me for examination, from the collection of Rutger's College, by Prof. Cook. The specimen, represented in Fig. 2, Plate X, resembles the tooth in the jaw fragment first described, or is of the form which is usually viewed as characteristic of *Mosasaurus*. It is perfect, except that the apex and anterior carinated ridge of the crown are worn, and it measures five inches and a half in length.

The length of the enamelled crown in its present condition is twenty-two lines; the antero-posterior diameter at base thirteen lines, and the transverse diameter fourteen lines. The outer and inner surfaces are defined by acute, linear ridges, which become more carinated towards the apex of the crown. The unworn posterior ridge is minutely denticulated, and traces of the same condition are visible on the anterior ridge. The outer surface of the crown is nine lines wide at the bottom and eight lines at the middle. It forms less than one-sixth of a circle, whose radius is about eight lines, and is irregularly subdivided into four planes below, extending into three towards the apex. The inner surface forms about three-fourths of a circle, whose radius is six lines, and is irregularly subdivided into eleven planes. The circumference of the crown at the enamel border is three inches and three-quarters, of which the inner surface is two inches and eleven lines, the outer surface ten lines. The accompanying outlines, No. 1, represent transverse sections of the crown at its base, a short distance above the base, and near the middle.

No. 1.

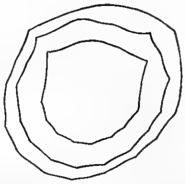


The exserted portion of the fang, or that which extends the cone of the crown, is from nine to ten lines high, and seventeen lines in diameter at base. The inserted portion is cylindrical, three inches in length, and rounded at the bottom. It was coossified with its alveolus, as indicated by firmly attached portions of bone to its inner side. Its canal of communication with the pulp cavity of the tooth is completely occupied by a coarser ossific substance. On the inner side posteriorly there exists an excavation, one inch and a half deep and three-quarters of an inch wide, being part of the cavity for a successional tooth.

4. A tooth, from the Green-sand of Freehold, Monmouth County, New Jersey, belonging to Dr. C. Thompson, and loaned to me for examination through Prof. Cook. It is represented in Fig. 1, Plate X, and is rather larger than the preceding specimen, which it resembles in form.

The enamelled crown, broken at the apex, when perfect measured about two inches and a half in length; its diameter at base antero-posteriorly is fourteen lines, transversely fourteen lines and a half. The outer and inner surfaces are defined by well-marked acute ridges, which are minutely denticulated. The outer surface is an inch wide at the bottom of the crown, three-fourths of an inch at its middle, and is subdivided into three planes. The inner surface forms more than half a circle, whose radius is about seven lines, and it is distinctly subdivided into eleven planes. The circumference of the crown at the enamel border is four inches, to which the inner surface contributes two inches ten lines; the outer surface fourteen lines. The accompanying outlines, No. 2, represent sections at the base of the crown, and from the lower and upper third.

No. 2.

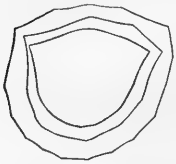


The fang is three inches and three-fourths in length, and appears not to have been coossified with its alveolus; at least it exhibits no traces of attached portions of the jaw. The bottom of the fang presents a wide elliptical pit, narrowing into a fissure, continuous with the canal of communication with the pulp cavity of the tooth. The inner side of the fang posteriorly presents an excavation (Fig. 1, *d*) for a successional tooth, and a second (*c*), shallower impression, to accommodate a successor to the functional tooth in advance.

5. The shed crown of a tooth, from near Woodbury, Gloucester County, New

Jersey, belonging to the museum of the Academy of Natural Sciences. It is represented in Fig. 3, Plate X, and was previously indicated and figured by Harlan[1] and Morton.[2] In form it resembles the corresponding portion of the teeth above described, but is slightly larger. Its dividing ridges are distinctly denticulated; the outer surface is divided towards the base of the crown into four planes, which diminish and finally disappear towards the apex; the inner surface is divided into eleven planes, which also diminish and become obsolete towards the apex. The length of the crown when perfect has been about two inches and three-quarters; the antero-posterior diameter at base about thirteen lines; and the transverse diameter is fourteen lines and a half.

No. 3.

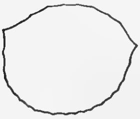


The base of the specimen is excavated in a trumpet-like manner, extending to a thin edge at the periphery of the crown. This condition evidently indicates the specimen to have been shed during the life of the animal, notwithstanding the little wearing to which the tooth appears to have been subjected.

The accompanying outlines, No. 3, represent sections from the base, middle, and near the apex of the specimen.

6. The shed crown of a tooth, from Burlington County, New Jersey, presented to the Academy of Natural Sciences by Mr. L. T. Germain. The specimen, represented in Fig. 6, Plate X, has the apex and base broken, but when perfect appears to have been less than two inches and a half long, about thirteen lines in diameter antero-posteriorly and twelve lines transversely. The ridges of the crown are distinctly denticulated, but separate the surfaces less unequally than in the preceding specimens. The outer surface is subdivided into nine planes, passing into seven and then becoming obsolete towards the apex of the crown. The inner surface is subdivided into about twenty planes, diminishing and finally disappearing towards the apex of the tooth. The subdivisional planes are more or less obscured by longitudinal striation of the enamel, more especially on the inner side. This striation diminishes and finally disappears towards the apex. It does not exist in the specimens previously described.

No. 4.



The accompanying outline, No. 4, represents a transverse section of the crown below its middle.

The base of the specimen is excavated towards the central pulp cavity in a salver-form manner from a broken edge at the periphery about a line and a half thick.

7. An entire tooth, from Monmouth County, New Jersey, loaned to me for examination, from the collection of Rutger's College, by Prof. Cook. The specimen represented in Fig. 3, Plate IX, I suspect to belong to the forepart of the lower jaw of *Mosasaurus*. It is smaller, but has the same general form as the entire teeth previously described.

The crown is more curved than in any of the preceding specimens, but like them

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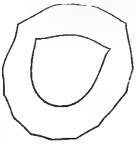
[1] Journ. Acad. Nat. Sci., Vol. IV, Plate XIV, Figs. 2, 3, 4; Med. and Physical Researches.

[2] Synopsis of Organic Remains, &c., Plate XI, Fig. 9.

presents its inner and outer surfaces separated by minutely denticulated ridges, and subdivided, though less distinctly, into narrow planes. The length of the crown is twenty-two lines; its antero-posterior diameter at base eleven lines; its transverse diameter twelve lines; its inner circumference twenty-eight lines; and its outer circumference eleven lines. The inner surface is obscurely subdivided into nine or ten planes, disappearing towards the apex of the crown; the outer surface into three or four planes, equally obscure, and disappearing in the same manner. The accompanying outlines, No. 5, represent sections at the base and near the apex of the crown.

No. 5.

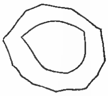


The fang is moderately curved, cylindroid, and measures about two inches and a half in length, of which the extra-alveolar portion comprises about half an inch. The bottom presents an elliptical funnel-shaped pit narrowing into the canal of communication with the pulp cavity. The sides of the fang exhibit no trace of excavations corresponding with cavities for successional teeth.

8. A tooth, from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by Dr. J. H. Slack. The specimen, represented in Fig. 2, Plate IX, resembles that last described so nearly that it looks as if it might have been derived from the same individual, though it is considerably smaller.

The crown is seventeen lines long, with the base eight lines in diameter antero-posteriorly and seven lines and a half transversely. The surfaces of the crown are less unequally divided than in the preceding specimen by the usual ridges, which in this case are rather obscurely denticulated. The outer surface of the crown is subdivided into four planes, merging into three and disappearing towards the apex; the inner surface is subdivided into eight planes, likewise becoming obsolete towards the apex. The accompanying outlines, No. 6, represent transverse sections of the crown from near the base and apex.

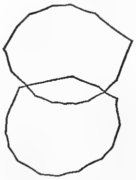
No. 6.



The fang is twenty-three lines long, and closely resembles that of the preceding specimen, in its form, the entrance to the pulp cavity, and in the absence of an excavation produced by a successional tooth.

9. A mutilated tooth, which accompanied the latter specimen, from the same locality and donor. It is larger and has a proportionately shorter and more robust fang than the preceding. The crown is more equally divided by the usual ridges, and the surfaces are more distinctly subdivided into planes; the outer surface exhibiting five, the inner surface nine. These indistinctly multiply near the base of the crown, and diminish in number and finally become obsolete towards the apex. The antero-posterior diameter of the base of the crown is eleven lines; the transverse diameter nine lines. The accompanying outline, No. 7, represents a transverse section near the base of the crown.

No. 7.



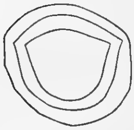
No. 8.

The fang is compressed from without inwardly, and measures two inches in length; sixteen lines antero-posteriorly, and twelve lines transversely. It presents no trace of a cavity for a successor, and the entrance to its pulp cavity is like that in the preceding specimen.

10. A mutilated tooth, from Burlington County, New Jersey, presented to the Academy of Natural Sciences by Charles C. Abbott. It is intermediate in form and size with the specimens numbered 7 and 8. The outer surface of the crown, corresponding with the antero-posterior diameter, is eight lines and a half, and it exhibits three planes. The inner surface exhibits eight planes, and the transverse diameter equals the former one. The accompanying outline, No. 8, represents a section near the base of the crown. The fang is curved cylindroid, slightly compressed, and measures two inches and a quarter in length. Its inner side posteriorly exhibits a small lenticular excavation, three lines long, produced by a successional tooth.

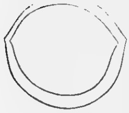
11. Two teeth, which have lost their fangs, from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by E. D. Cope. The specimens, represented in Fig. 5, Plate X, and Fig. 12, Plate XI, look as if they had been derived from the same individual. They correspond in form with the more familiar one viewed as characteristic of *Mosasaurus*, but they are smooth or devoid of subdivisional planes, or at most exhibit only the feeblest disposition to their development at the base of the crown. The pulp cavity, within the specimens, presents the outward form of the crown. The length of the more perfect specimen, Fig. 5, from the enamel border of the base of the crown to the worn apex, is twenty-two lines; its antero-posterior diameter at base is eleven lines; its transverse diameter the same. The accompanying outlines, No. 9, represent transverse sections near the base of the crown, and just below and above the middle. The length of the crown of the other specimen, Fig. 12, is two inches.

No. 9.



12. An entire tooth, from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by Dr. J. H. Slack. It is represented in Fig. 4, Plate IX, and is intermediate in size with those of the approximate Figs. 2 and 3, to which it also bears a general resemblance in form.

No. 10.

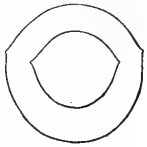


The unworn crown is twenty lines long, and is nearly circular in transverse section, as represented in the accompanying outlines, No. 10, taken from the base and below the middle. The diameter of the base of the crown antero-posteriorly is ten lines and a half; the transverse diameter nine lines and a half. The ridges separating the surfaces of the crown are minutely denticulated, and both surfaces are smooth or entirely devoid of subdivisional planes and striations. The inner surface is a little more extensive than the outer one, as represented in the accompanying sections.

The fang is straight, cylindroid, and measures two inches and a half in length and thirteen lines in diameter. It exhibits no evidence of having been coossified with its alveolus, and on the inner side posteriorly, as represented in Fig. 4, *b*, it presents a small excavation for the accommodation of a successional tooth. At the free extremity it presents a funnel-shaped pit, prolonged into the central canal of communication with the pulp cavity.

13. A tooth, which has lost its fang, from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by Charles C. Abbott. It is represented in Fig. 11, Plate X, and measures two inches in length. Its apex is worn, and it is invested with enamel to the extreme base of the specimen. It bears a near resemblance to the crown of the preceding specimen, but is much larger. The base is circular in section, and measures an inch in diameter. The inner surface is slightly more extensive than the outer one, as seen in the accompanying sections, No. 11, taken from the base and above the middle of the crown. Both surfaces are devoid of the faintest trace of subdivision into planes, and are separated by the usual minutely denticulated ridges. The centre of the broken base of the crown exhibits the funnel-shaped summit of the pulp cavity, the wall of which at the broken border of the specimen is four lines thick.

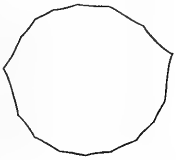
No. 11.



14. Nine teeth, coossified with small attached portions of the jaw, from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by Dr. J. H. Slack. They were found together in the same marl pit, and have every appearance of having belonged to the same individual.

One of the specimens, represented in Figs. 8, 9, Plate X, is about five inches and a half in length. The apex of the crown is worn off more than in any other specimen of the kind I have ever seen. The dividing ridges are also considerably worn, though enough of one remains to ascertain that they were minutely denticulated. In its present condition the crown is two inches long, and its nearly circular base measures fourteen lines and a half antero-posteriorly and fourteen transversely. The inner side is more extensive than the outer; the former being twenty-six lines in circumference at its base, the latter twenty lines. The inner surface is distinctly subdivided into nine planes; the outer into seven. The accompanying outline, No. 12, represents a transverse section near the base of the crown.

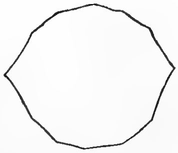
No. 12.



The extra-alveolar or exserted portion of the fang continues the cone of the crown, and is fourteen lines long by about two inches in diameter at the base. The intra-alveolar portion of the fang is two inches and three-quarters long, and appears to be a constituent portion of the jaw, so intimately is it coossified and continuous with its alveolus. Its inner side posteriorly is deeply excavated, as represented in Fig. 8, *c*, for the accommodation of a successional tooth.

A second specimen, represented in Fig. 7, Plate X, closely resembles the former, except that the inner and outer surfaces of the crown are nearly equal in extent, and are each divided into six principal planes, of which one presents a partial but feeble subdivision. The crown, very much worn at the apex and along the anterior ridge, in its present condition is two inches in length, and thirteen lines in transverse diameter at base, while the antero-posterior diameter has been about fourteen lines. The inner circumference of the base is about twenty-three lines, the outer twenty-two lines.

No. 13.

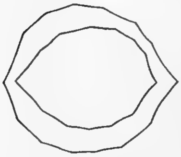


The accompanying outline, No. 13, represents a transverse section taken from near the base of the crown. The fang is three inches and three-quarters in length, and exhibits a cavity for a successional tooth like that of the preceding specimen.

Attached to the same specimen, but not represented in the figure, there is a coossified fragment of the fang of the tooth, which was situated in advance, and which was about one-half excavated to accommodate a successional tooth.

A third specimen, much mutilated, nearly resembles the former one. The inner and outer surfaces of the crown are nearly equal in extent, and each is subdivided into seven planes. The antero-posterior diameter at the base is fourteen lines and three-quarters; the transverse diameter thirteen lines. The outer of the accompanying outlines, No. 14, represents a section at the base of the crown.

No. 14.



The fang is half excavated away at the inner side and bottom for the accommodation of a successional tooth. The excavation just below the level of the extra-alveolar portion of the fang communicates with the pulp cavity its entire breadth.

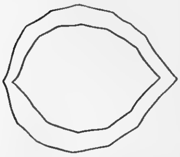
A fourth specimen, much mutilated, bears a near resemblance with the former two, but is considerably smaller. The crown, from its worn apex to the base, is sixteen lines long; its antero-posterior diameter at base is twelve lines and a half; the transverse diameter ten lines. The inner and outer surfaces are nearly equal in extent, but the latter is even slightly the greater, and is divided into seven planes, while the former is divided into six. The inner of the accompanying outlines, No. 14, represents a section of the crown near the base,—appearing more elliptical than in preceding sections.

The fang is about two inches and three-quarters long, and is nearly half excavated for a successor. The excavation communicates with the open canal of the pulp cavity.

The fifth specimen, represented in Fig. 5, Plate IX, consists of a tooth, together with the fang of a second, coossified with an alveolar fragment of the jaw.

The crown of the tooth has its apex broken and its posterior ridge worn. When perfect it appears to have been about two inches long; and its elliptical section at base measures fifteen lines antero-posteriorly and thirteen transversely. The inner and outer surfaces are nearly equal, the former being subdivided into six, the latter into eight unequal planes. The accompanying outlines, No. 15, represent sections near the base and middle of the crown.

No. 15.



The fang of the tooth is three inches and three-quarters long, and is one-half excavated antero-internally for the accommodation of a successional tooth, as represented in Fig. 5, *e*. The excavation communicates with the pulp cavity on a level with the bottom of the extra-alveolar portion of the fang, as seen at *f*.

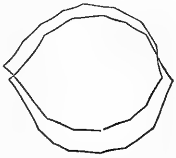
The fang of the other tooth is about one-third excavated postero-internally, as represented on the right of Fig. 5, *e*, and the excavation has exposed the pulp cavity of the tooth as seen at *f*.

The contiguous sides of the two fangs are likewise excavated together for the accommodation of a successional tooth, as seen at the middle of Fig. 5, *e*, and thus the two teeth exhibit cavities for the accommodation of three successors.

The sixth specimen is represented in Fig. 6, Plate IX, and consists of a tooth of nearly the same size and form as that in the specimen last described.

The crown when perfect has measured over two inches in length; and at base it measures fourteen lines in diameter antero-posteriorly, and twelve lines and a half transversely. The inner surface is rather more extensive than the outer, and is divided into seven planes, while the latter presents six planes. The curve of the base of the inner surface measures two inches, that of the outer surface twenty lines. The lower of the accompanying outlines, No. 16, represents a section near the base. The fang upon its inner part is almost one-half excavated to accommodate a successor, as represented in Fig. 6, *e*. The excavation has exposed the lower half of the pulp cavity, seen at *f*.

No. 16.



The seventh specimen consists of an entire tooth, represented in Fig. 10, Plate X, nearly resembling the two last described teeth.

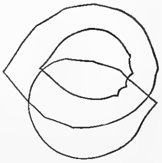
The crown is two inches in length, elliptical in transverse section, and measures at base antero-posteriorly fourteen lines and a half; transversely twelve lines. The inner and outer surfaces are nearly equal, and are rather less distinctly subdivided into planes than in the preceding specimens which accompanied this one. The upper of the accompanying outlines, No. 16, represents a section near the base of the crown.

The fang anteriorly and postero-internally presents two excavations for the accommodation of successional teeth, as represented in Fig. 10, *c*, *d*. The postero-internal excavation communicates with the pulp cavity, as seen at *e*.

The eighth specimen, represented in Fig. 4, Plate X, has the general form and proportions of its companions, but is smaller, except the fourth specimen above indicated, which it most nearly resembles.

The crown is twenty-two lines long, elliptical in transverse section, and measures fourteen lines in diameter at the base antero-posteriorly, and eleven lines and a half transversely. Its most remarkable peculiarity consists in the possession of a single carina or ridge situated posteriorly along the concave border; the ridge being minutely denticulated as in those of preceding specimens. The anterior border of the crown is thick and convex, and towards the apex presents several prominent vertical folds. The inner and outer surfaces, of equal extent, are feebly subdivided into traces of from four to six planes. The upper pair of accompanying outlines, No. 17, represent transverse sections near the base and apex of the crown. The fang is deeply excavated postero-internally, as seen in Fig. 4, *d*, for the accommodation of a successor, but the excavation has not exposed the pulp cavity of the tooth.

No. 17.



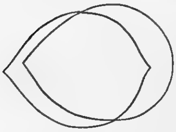
The ninth, or remaining specimen of the series under examination, is represented in Fig. 5, Plate XI, and is a miniature resemblance of the tooth last described. The crown when perfect has measured less than three-fourths of an inch in length, is elliptical in transverse section, and measures at base five lines and three-quarters antero-posteriorly, and four lines and a half transversely. Its single posterior carinated ridge is minutely denticulated as in the large teeth, and the surfaces are devoid of planes.

The fang, independent of the alveolar fragment with which it is coossified, measures about an inch and a half long, and has at its inner side posteriorly a deep excavation for a successional tooth, as seen in Fig. 5, *a*.

15. A perfect tooth, coossified with a fragment of the jaw, from Monmouth County, New Jersey, loaned by William Cornell, through Prof. Cook. The specimen was received after the present memoir and its accompanying plates were nearly completed. It closely resembles the eighth specimen of the series above described. The crown is unworn, is twenty lines long, and is elliptical in transverse section. Its base is one inch in diameter antero-posteriorly, and nine lines and a half transversely. It possesses a single ridge, situated along its posterior or concave border; and the surfaces are smooth, except that the outer one presents a feeble disposition to subdivision into four planes. The lower of the accompanying outlines, No. 17, represents a section from near the base. The fang is three inches long.

16. Two teeth, from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by Dr. J. H. Slack. One of the specimens resembles the two large ones last described. The crown has the apex broken off, but is otherwise perfect. Its transverse section is elliptical, and measures at base antero-posteriorly thirteen lines; transversely ten lines and a half. It possesses a single carina, situated posteriorly, and the surfaces are totally devoid of planes. The accompanying right hand outline, with one point, No. 18, represents a section near the base. The fang is about three inches long, and exhibits on its inner side near the centre a slight excavation, five lines long, as the commencement of a cavity for a successor. The canal communicating with the pulp cavity through the fang is open.

No. 18.



The second specimen, represented in Fig. 7, Plate IX, is nearly perfect, and measures about four inches and a half long. It corresponds in all its anatomical characters with the teeth described by Prof. Owen as characteristic of a distinct genus, to which he has given the name of *Leiodon*.

The crown is twenty-one lines long, elliptical in transverse section, as represented in the accompanying left hand outline, with two points, No. 18, and measures at base antero-posteriorly thirteen lines; transversely eleven lines. Minutely denticulated ridges divide it in the usual manner into inner and outer surfaces of nearly equal extent and convexity and totally destitute of subdivisional planes.

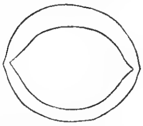
The fang is straight, and presents no trace of having been coossified with its alveolus, as is also the case with that of the preceding specimen. It further exhibits no trace of a cavity for a successional tooth.

17. The shed crown of a tooth, from St. Georges, New Castle County, Delaware, contained in the museum of the Academy of Natural Sciences. It is represented in Fig. 11, Plate IX, and resembles the corresponding part of the tooth just

described. It also bears a near resemblance to a specimen described by Prof. E. Emmons,[1] under the name of *Elliptonodon compressus.*

The enamelled crown is an inch and a half long, and is elliptical in transverse section, as represented in the accompanying outlines, No. 19, representing sections below the middle and at the base. The latter measures an inch antero-posteriorly, and ten lines transversely. The acute ridges divide the crown into two surfaces about equal in extent and convexity. The surfaces exhibit a faint disposition to subdivide towards the base, but for four-fifths of their length are smooth. The transverse annulation, represented by the artist in the figure, is only one of staining of the enamel, though there is a feeble constriction of the crown corresponding with the band above its middle. The base of the specimen is excavated in a funnel-shaped manner from a thin sharp edge at the periphery to the central pulp cavity.

No. 19.

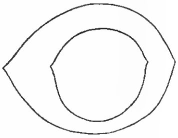


18. Two specimens of teeth, from Mount Holly, Burlington County, New Jersey, contained in the museum of the Academy of Natural Sciences.

One of the specimens, represented in Fig. 9, Plate IX, consists of the shed crown of a tooth, much worn at the apex. In its present condition it measures nineteen lines long, extending from the enamel border at the base, and in transverse section is elliptical, as represented in the outer of the accompanying outlines, No. 20. The antero-posterior diameter at base, in the perfect condition, measured sixteen lines, and the transverse diameter is thirteen lines and a half. The surfaces, about equally divided by the anterior and posterior acute ridges, are entirely devoid of subdivisional planes. The enamel is more rugose than in any of the preceding teeth, but otherwise I can see no important difference between it and several of those last described. The base is excavated in a salver-form manner, from a broken edge about a line in thickness, to the central pulp cavity.

The second specimen, represented in Fig. 10, Plate IX, consists of a comparatively small tooth, with the apex of the crown broken off so as to expose the summit of the pulp cavity. In color and general character the specimen looks as if it may have belonged to another part of the dental series of the same individual as its larger companion.

No. 20.



In form the crown has nearly resembled that of the specimen described as No. 12, represented in Fig. 4, Plate IX. When perfect it has measured about thirteen lines long; and its circular base is eight lines in diameter. It is irregularly divided by the acute ridges, of which the anterior is almost entirely obliterated by wear. The inner surface is much more extensive than the outer, and both are smooth, presenting neither trace of subdivisional planes nor rugosities. The inner curve of the base is fifteen lines and a half, the outer curve eleven lines. The inner of the accompanying outlines, No. 20, is a transverse section from the base of the crown.

The straight fusiform fang is two inches and a quarter long, and appears as if it had not been coossified with its alveolus. Just back of the centre of the inner side

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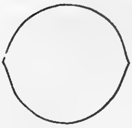
[1] North Carolina Geological Survey, 222, figs. 41, 42.

of the intra-alveolar portion it exhibits a shallow niche, about five lines long, as a commencing cavity for a successor.

19. The shed crown of a tooth, from Freehold, Monmouth County, New Jersey, sent to me for examination from the collection of Dr. C. Thompson, through Prof. Cook. It is represented in Fig. 8, Plate IX; is somewhat water-worn, and has lost its apex. It resembles the crown of the last described specimen, but is larger and has its surfaces equally divided by the anterior and posterior ridges. The diameter of the nearly circular base, represented in the accompanying outline, No. 21, is ten lines and a half antero-posteriorly, and ten transversely.

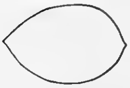
No. 21.



20. A tooth, coossified with its alveolus, from Monmouth County, New Jersey, loaned by O. R. Willis, through Prof. Cook. It is represented in Fig. 10, Plate XI, and is two inches and three-quarters long.

The crown resembles that of the specimens described under Nos. 16, 17, 18, and represented in Figs. 7, 9, 11, Plate IX, except that it is more compressed and curved in relation with its length. It presents the form viewed as characterizing the genus *Leiodon*, and is about equally divided by the usual pair of ridges into two surfaces, which are smooth. The length of the crown is fifteen lines; its antero-posterior diameter at base ten lines and a half; its transverse diameter seven lines. The transverse section is elliptical, with acute poles, as represented in the accompanying outline, No. 22.

No. 22.



The fang is of unusual breadth, in comparison with its length, and is compressed from without inwardly. Postero-internally it is deeply excavated, as seen in Fig. 10, *c*, for the accommodation of a successional tooth.

21. The fragment of a jaw containing two teeth, from Monmouth County, New Jersey, presented by Dr. J. H. Slack to the Academy of Natural Sciences. It is represented in Figs. 6, 7, Plate XI, and bears a near resemblance to the corresponding portions of a specimen figured by Dr. Morton [1] and loaned to him by Dr. De Kay as characteristic of *Geosaurus Mitchelli*.

The jaw fragment is three inches and a half long, and is broken away along the line of the dental canal, at the bottom of the alveoli. Its outer surface is vertically moderately convex, and presents at the broken border a row of three vasculo-neural foramina communicating with the remains of the dental canal. The two extremities of the specimen exhibit portions of alveoli, from which teeth appear to have been lost together with their fangs. Postero-internally to the portion of the anterior alveolus (*f*) there is an excavation (*e*) for a successional tooth.

The intermediate portion of the fragment contains the fang (*c*) of a shed tooth, coossified with the jaw and containing a successor (*d*), and an entire tooth (*a*) occupying a functional position behind the former.

The fang (*c*) of the shed tooth is so intimately coossified with the jaw as almost to appear as a constituent portion of the latter. The extra-alveolar portion of the fang presents a funnel-shaped excavation or crater, communicating at bottom by

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[1] Synopsis of the Organic Remains of the Cretaceous Group, etc., p. 28, Plate XI, Fig. 10.

an orifice with the excavation for the successional tooth. The latter excavation nearly involves the whole of the intra-alveolar portion of the fang. The contained tooth (Fig. 6, *d*, Fig. 7) is a fully developed crown, with a large interior pulp cavity, extending to the thin edge of the developing fang as usual in dentition. It resembles that of the last described specimen, but is shorter and more robust in its proportions. Further, the acute ridges divide the crown unequally, the outer surface being more extensive and convex than the inner. The surfaces also are strongly wrinkled longitudinally, especially towards the base, and there exists an evident disposition to subdivide into planes, especially on the outer surface, as represented in Fig. 7. The crown is thirteen lines and a half long, elliptical in transverse section, as represented in the accompanying outline, No. 23. The antero-posterior diameter of the slightly contracted base is nine lines; the transverse diameter eight lines. The inner curvature of the base is nine lines and a half, the outer curvature fifteen lines and a half.

No. 23.

The tooth (Fig. 6, *a*) occupying a functional position behind the preceding has the crown considerably worn at the apex, and the enamel is also partly worn away at the base antero-externally, and on several positions of the dividing ridges. It resembles the unworn crown occupying the cavity in advance, but the appearance of a tendency in the surfaces to subdivide into planes is less obvious, and, indeed, is hardly evident on the external surface, where it is most so in the other tooth.

The fang is intimately coossified with its alveolus, and a deep excavation (*b*) exists at its posterior part internally for a successional tooth. The exserted portion of the fang is eight lines long, and at the alveolar margin occupies a breadth antero-posteriorly of sixteen lines, transversely thirteen lines.

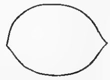
22. Fragments of both sides of the lower jaw, and of both pterygoid bones, with teeth, from the same individual. The specimens were obtained from the Greensand of Holmdel, Monmouth County, New Jersey, and have been submitted to my examination by Prof. Reiley, of Rutger's College, through Prof. Cook. The teeth preserved in the fragments resemble those above described which have the laterally compressed, smooth crown, and correspond with those which have been viewed as characteristic of the genus *Leiodon.*

A fragment of the back part of the right dental bone, represented in Fig. 3, Plate XI, contains a perfect tooth, apparently the penultimate, a portion of the alveolus behind, and portions of the two alveoli in advance.

The outer surface of the bone is a vertical plane, rounded at the alveolar border and broken at the lower. The back end is broken off, and the oblique border below is that for articulating with the coronoid bone behind. A large vasculo-neural foramen, opening into the dental canal along the middle of the specimen, is situated below the tooth retained in the specimen. Part of a similar and smaller foramen is also situated rather higher at the anterior broken border.

The tooth preserved in the fragment has its fang coossified with the alveolus and the border of the jaw. It bears a near resemblance with the specimen described under No. 20. The crown, situated somewhat obliquely with its outer face directed forward, is an inch

No. 24.



long, and is divided by minutely denticulated ridges into two smooth surfaces, of which the outer is slightly the larger. The transverse section, as represented in the accompanying outline, No. 24, is elliptical, and the antero-posterior diameter at the slightly constricted base is nine lines and three-quarters; transversely six lines and a half.

The extra-alveolar portion of the fang is half an inch high; sixteen lines in diameter antero-posteriorly at the alveolar border, and eleven lines transversely. The intra-alveolar portion of the fang is an inch long, and encroaches for half its length within the dental canal.[1] Postero-internally, together with the contiguous portion of the jaw, it is excavated into a cavity which contains the crown of a successional tooth.

The alveolus in advance retains the outer half of a coossified fang, which was about a third excavated for a successor. The portions of the alveoli at the anterior and posterior border have the appearance as if their former occupants had been lost entire, crown and fang together.

A fragment of the left dental bone, of which Fig. 4, Plate XI, represents an inner view of part of the specimen, nearly corresponds with the former one of the opposite side. The entire tooth it contains corresponds in position with that in advance of the one preserved in the former. The tooth larger than in the preceding specimen is like it in form. The crown, with its apex considerably worn, thus reduced, is thirteen lines long; is nine lines and three-quarters in diameter at base antero-posteriorly, and seven lines and a half transversely. The fang is two inches long, and the dental canal pursues its course just external to its bottom.

The specimen is especially interesting from the circumstance that the successional tooth (*c*), inclosed in the cavity of the fang (*b*) in advance, having been accidentally partially broken away, exhibits in the interior a minute successor (*d*). It thus appears that in the succession of development of the teeth of *Mosasaurus* a new tooth originates within its predecessor, while this is still contained in the excavated fang of the tooth occupying a functional position at the border of the jaw. As the latter is displaced by its successor it would appear that as the crown of this protrudes from the jaw the new tooth is excluded from its place, and is made to assume a position on the exterior of the fang of its parent. The new tooth, as if desirous of once more obtaining admission into the position from which it had been excluded, in its growth induces absorption of the fang of its predecessor so as to accommodate its increasing size.

Two fragments of the right pterygoid bone, represented in Figs. 1, 2, Plate XI. The larger fragment contains a tooth and the fangs and alveoli of four others; the smaller fragment contains two teeth, part of another, and part of a large successional cavity which appears to correspond with a similar part at the end of the larger fragment. It would thus appear that there were eight teeth to the full series, corresponding in this respect with the number of pterygoid teeth in the Maestricht Monitor. The anterior teeth, however, are very much larger than in

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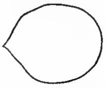
[1] The artist neglected to represent in the figure the bottom of the fang, visible through the vasculo-neural foramen, so that the tooth looks actually acrodont.

the latter, and, indeed, they so far exceed them in relation with the size of the mandibular or maxillary teeth that I for a long time hesitated in admitting the fragments to belong to the pterygoid bone, and suspected that they belonged to part of the upper jaw. The anterior extremity of the larger fragment, however, exhibits sutural marks, and the fang of the first tooth indicates this to have been smaller than those immediately succeeding it. The second, third, and fourth teeth were the largest of the series and nearly equal in size; then followed in size the first and fifth, which were nearly equal, and finally the sixth to the eighth, which became successively smaller.

The anterior pair of fangs (Fig. 2, *a*, *b*) preserved in the larger fragment are coossified with their alveoli, and include in cavities on their inner side posteriorly the mutilated remains of successional teeth. Succeeding the fangs indicated there is a large vacant alveolus (*c*), from which the former occupant has been lost, fang and crown together. Then follows a tooth (*d*), with the end of the crown broken, and the fang coossified with its alveolus.

The tooth, from the broken apex of the crown to the bottom of the fang, is two inches and ten lines long. The crown, in shape and construction, resembles those described under Nos. 14 and 16, which have only a single acute ridge along the posterior or concave border of the crown. The surfaces are devoid of subdivisional planes, though there is a slight tendency to their development externally. The transverse section is ovate, as represented in the accompanying outline, No. 25. The antero-posterior diameter at the base is nine lines; the transverse diameter seven lines. The fang on its inner side presents a small excavation containing the remains of a successor.

No. 25.



Back of the tooth described is a vacant alveolus, from which its former tenant has been lost, crown and fang together. To the inner side posteriorly of this vacant alveolus there is a small cavity for a successional tooth which had been destined to occupy the former.

Above the fangs of the teeth the bone internally presents a large space or groove into which the bottoms of the alveoli for a short distance protrude.

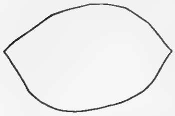
The two teeth, occupying the small or posterior fragment of the pterygoid bone (Fig. 1), are miniatures of the tooth preserved in the anterior fragment, and closely resemble the last of the series described under No. 14, and represented in Fig. 5, Plate XI. The crown of the foremost of the two teeth has its apex broken, and measures at base five lines and a half antero-posteriorly, and four lines and a quarter transversely. The crown of the last tooth is half an inch long, four lines and a quarter in diameter at base antero-posteriorly, and three lines transversely.

23. The crown of a small tooth, which has lost its fang, from Burlington County, New Jersey, presented to the Academy of Natural Sciences by T. A. Conrad. It is represented in Fig. 15, Plate XI, and resembles the crowns of the two teeth last described, like them having but a single acute ridge at the back or concave border. Its apex is worn off, but in its perfect condition it measured about an inch in length. Its ovate base is seven lines and a half in diameter antero-posteriorly, and six lines transversely.

This specimen apparently serves to fix the true character of a similar one obtained by Prof. Emmons at Elizabethtown, Cape Fear, North Carolina, and described by me under the names of *Drepanodon impar*[1] and *Lesticodus impar.*[2]

24. A tooth, differing from any other specimens in its soft, chalky consistence and ochre color, from near Hanover, Burlington County, New Jersey, contained in the museum of the Academy. The crown is worn and broken at its apex, and when perfect appears to have been near two inches long. It is elliptical in section, and not quite equally divided by the usual ridges into two surfaces, which exhibit an obscure disposition to subdivide into planes. The antero-posterior diameter of the base of the crown is fourteen lines, the transverse diameter ten lines. The accompanying outline, No. 26, represents a section at the base of the crown, of which the inner curve is twenty-one lines, the outer seventeen lines.

No. 26.



The fang is two inches and a half long, nearly two inches in breadth from before backward, and one inch and a quarter transversely. It is about one-third excavated at the bottom and postero-internally for a successional tooth, but the excavation does not expose the pulp cavity, except through two narrow vasculo-neural canals of the fang.

25. A much mutilated tooth, from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by Charles C. Abbott. The crown nearly resembling that last described, both in size and form, has the remains of the inner surface rather more distinctly subdivided into planes, and is slightly striated at the base. The outer surface, nearly all destroyed, in the small remaining portion gives evidence of its also having been more distinctly subdivided than in the former specimen. The antero-posterior diameter of the base of the crown is thirteen lines, and its transverse diameter has been about nine lines.

The fang, preserved entire, unexcavated, and without evidence of having been coossified with its alveolus, is particularly remarkable for its small size, in relation with the crown, in comparison with other specimens. It measures an inch and a half long, is nearly as broad, being seventeen lines antero-posteriorly, and is ten lines transversely.

The interior pulp cavity of the tooth appears as a large compressed fusiform receptacle, extending as nearly to the end of the fang as it does to the summit of the crown.

26. A mutilated tooth, from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by Dr. J. H. Slack. The crown had nearly the same form as that of the preceding specimen, but it is smaller, and the surfaces are distinctly subdivided into planes. The antero-posterior diameter of the base of the crown is 11 lines, the transverse diameter seven lines and three-quarters.

27. Two shed crowns of teeth, nearly alike, one from St. George's, New Castle County, Delaware, presented to the Academy of Natural Sciences by T. A. Conrad;

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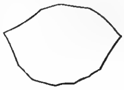
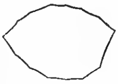
[1] Proc. Acad. Nat. Sci. 1856, VIII, 255; Report of the North Carolina Geological Survey, 1858, 224, Figs. 45, 46.

[2] Proc. Amer. Philos. Soc., 1859, VII, 10.

the other from near Woodbury, Gloucester County, New Jersey, presented to the Academy by Dr. J. L. Burtt. The former is represented in Fig. 12, Plate X; the latter in Fig. 13, of the same Plate.

No. 27.





No. 28.

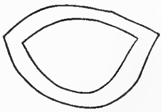
They resemble the crown of the tooth last described, but are in a better condition of preservation. They are divided in the usual manner into two surfaces, of which the inner is rather more convex than the outer, and both are distinctly subdivided into planes. The New Jersey specimen, of which the outline, No. 27, represents a transverse section, presents four planes on its outer side and seven on its inner side; and it measures eighteen lines in length, nine lines and three-quarters antero-posteriorly at base, and seven lines transversely. The Delaware specimen, of which the outline, No. 28, is a section, exhibits seven planes externally and internally, and measures seventeen lines long, nine lines and a quarter antero-posteriorly at base, and six lines and a half transversely.

28. A tooth, from Mount Holly, Burlington County, New Jersey, presented to the Academy of Natural Sciences by Dr. S. G. Morton. The crown has its apex broken off, and the ridges dividing the former are considerably worn. When perfect it has been about an inch and a half long, with the base ten lines and a half antero-posteriorly, and eight lines transversely. The surfaces are devoid of subdivisional planes, or exhibit only the faintest traces of several towards the back border of the crown. The inner surface more convex than the outer, has the curve of its base eighteen lines in width, while the outer one is thirteen in width.

The fang is entire, and appears not to have been coossified with its alveolus. The exserted portion forms a curved shoulder measuring externally only five lines in length, while at the border it is sixteen lines in antero-posterior diameter, and thirteen lines in transverse diameter. The intra-alveolar portion of the fang is an inch and a half long, straight, somewhat compressed, and tapering below. On its inner side posteriorly is a small excavation for a successional tooth.

29. A fragment of a jaw, with portions of three alveoli, of which one contains the fang of a tooth deeply excavated and containing a successor. The specimen is from Marlboro, Monmouth County, New Jersey, and was loaned to me, from the collection of Rutger's College, by Prof. Cook.

No. 29.



The successional tooth, of which an inner view is represented in Fig. 11, Plate XI, is a crown with a large interior pulp cavity and thin walls. From the apex to the broken edge of the base it measures about twenty-two lines in length. In transverse section it is irregularly elliptical, as represented in the outlines, No. 29; its inner curvature being more convex and longer than the outer. The anterior and posterior acute ridges are minutely denticulated, and the surfaces they separate are totally devoid of subdivisional planes.

30. Two small teeth, from Freehold, Monmouth County, New Jersey, belonging to the collection of Dr. C. Thompson, and loaned to me through Prof. Cook. They are represented in Figs. 14, 15, Plate X, and appear to have belonged to the same individual.

They have the same general construction as the teeth above described, but in some respects are peculiar. The crown is demi-conical, curved backward, and divided before and behind by acute ridges with obscure traces of denticulation. The outer surface, the reverse of the ordinary condition in preceding specimens, is much more extensive and convex than the inner one, and both are devoid of subdivisional planes.

The crown of the smaller specimen, Fig. 14, has its point slightly bent outwardly; externally is nine lines long, with the curvature of the base thirteen lines; the curvature of the base internally is eight lines. The antero-posterior diameter of the base is seven lines; the transverse diameter five lines. The outline, No. 30, represents a transverse section below the middle of the crown.

No. 30.

The crown of the larger specimen, Fig. 15, has its apex broken off, but when perfect was about an inch long. The base is eight lines in diameter antero-posteriorly, and five lines and three-quarters transversely. The curve of the external surface at bottom is fourteen lines; that of the internal surface eight lines. The outline, No. 31, represents a transverse section near the base of the crown.

No. 31.

The fang presents the usual characters described in the preceding specimens, but the excavation corresponding with the cavity for successional teeth is more median in its position than in the others, as represented in Fig. 15, *c*.

31. A fragment of the left side of a lower jaw from Monmouth County, New Jersey, presented to the Academy of Natural Sciences by Charles C. Abbott. It is apparently from the fore part of the mandible of a young *Mosasaurus*, and is of special interest because it contains the fangs of three teeth, of which one is firmly coossified with its alveolus, while the others are loosely inserted. The specimen, from which the inner part of the bone has been removed to exhibit the fangs of the teeth, is represented in Fig. 8, Plate XI.

The fragment of jaw is five inches in length, and at its middle is an inch and three-quarters in depth. Its outer surface forms about one-third of a cylinder, and just above the middle presents a row of four large vasculo-neural foramina, communicating with the dental canal, which pursues its course exterior to the bottoms of the included fangs of the teeth. A row of smaller foramina exists also near the base of the fragment. Near the alveolar border, opposite the posterior of the contained fangs, the jaw is an inch and a quarter thick. The inner side of the base, as seen in the figure, exhibits the sutural marks for the splenial bone.

The coossified fang of the specimen is intermediate to the others, and is nearly half excavated to accommodate a successor which it still retains, as seen in Fig. 8, *d*.

The successional tooth, of which an outer view is also given in Fig. 9, is a narrow, much curved, conoidal crown, about fourteen lines long; six lines wide at base antero-posteriorly, and five lines and a quarter transversely. It is divided in the usual manner by a pair of minutely denticulated ridges into two surfaces, which are smooth and devoid of subdivisional planes. The inner surface more convex and extensive than the outer, presents a curvature at base of eleven lines, while the outer curvature measures seven lines. The outline, No. 32, represents a transverse section near the base of the crown.

No. 32.

The loosely inserted fangs in advance and behind the one containing the successional tooth, appear never to have been coossified with their alveoli. The foremost one, in the usual position postero-internally, presents a shallow lenticular depression a couple of lines in length, the earliest appearance of a cavity for a successional tooth. This escaped the notice of the artist, and has therefore been inadvertently left out of the figure. The posterior fang (*b*) exhibits a large and conspicuous excavation (*c*).

The remains of alveoli at the broken ends of the specimen exhibit coossified portions of fangs, with large excavations indicating them to have been like the one preserved with its contained successor.

This very instructive specimen, in the successive development of the teeth, certainly shows that the crown of the new tooth is developed at the postero-internal portion of the alveolus, and induces a gradual absorption in the contiguous simply inserted fang to accommodate itself. As the crown continues to grow its containing cavity enlarges at the expense of the fang of the old tooth, which in the meantime becomes coossified with its alveolus as if to strengthen its position or resist expulsion, which might indeed readily take place, were it not for the coossification. After the new crown has reached its full growth, it is followed by the development of its fang which causes the protrusion of the former, while the old fang is reduced to a mere chimney or tube bushing or investing the alveolus.

32. A tooth, which has lost the intra-alveolar part of its fang, from Mullica Hill, Gloucester Co., New Jersey, presented to the Academy of Natural Sciences by Dr. W. C. Hartman. It is represented in Fig. 16, Plate X; and has nearly the size and form of the successional tooth in the fragment last described.

The crown, somewhat worn at the apex, is an inch and a quarter long, and about six lines and a half in diameter at base antero-posteriorly, and five lines and three-quarters transversely. An acute ridge divides it anteriorly, which is not perceptibly denticulated; a posterior ridge is undeveloped, that is to say, in what appears to be the position it might occupy, there is only a feeble elevation like those which subdivide the surfaces of the crown. The outer of the latter exhibits five planes disappearing beyond the middle of the crown. The inner surface, towards the base, exhibits less distinctly nine subdivisional planes. The outline, No. 33, represents a section near the base of the crown.

No. 33.

33. The crown of a tooth, which has lost its fang, from a Cretaceous formation of Alabama. The specimen was loaned to me by Dr. R. W. Gibbes, who described and figured it in his Memoir on Mosasaurus and the allied genera,[1] page 9, plate III, figs. 6-9, and referred it to an extinct Saurian under the name of *Holcodus acutidens.* The specimen, represented in Fig. 17, Plate X, has the enamelled crown three-fourths of an inch in length. The base is elliptical in transverse section, and measures five lines antero-posteriorly, and four lines transversely. The crown is nearly equally divided by acute ridges, which are imperfect in the specimen, but appear not to have been denticulated. The surfaces are subdivided into narrow,

slightly depressed planes, and the inner one is strongly striate at base. The bottom of the exposed pulp cavity of the crown is two lines and a half by one line and three-quarters in diameter.

34. Two imperfect specimens of teeth, obtained by Dr. Hayden from the Cretaceous formation Number 4, at the mouth of White River, Nebraska. One of them, represented in Fig. 18, Plate X, is the shed crown of a small tooth, resembling the preceding, except that it is slightly narrower in proportion to its length, and the surfaces, though generally more striate, are almost devoid of subdivisional planes, especially the inner one. Its length is ten lines, the antero-posterior diameter of the oval base four lines and three-quarters, and the transverse diameter four lines. The second specimen, Fig. 19, consists of portions of both fang and crown of a tooth, which appears to have resembled the former one.

35. The fragment of an upper jaw of the right side received for examination from the Museum of the Smithsonian Institution. It is labelled *Leiodon*, from near Marion, Alabama, and the adherent matrix indicates that it had been imbedded in a soft cream-colored limestone, resembling the coarser varieties of chalk. It measures four inches along the alveolar border, and contains three fangs, from which the crowns have been broken off. The outer surface is longitudinally straight, vertically convex, and is rough. About an inch above the alveolar border it exhibits a transverse row of vasculo-neural foramina communicating with a dental canal within. The intermediate of the three fangs preserved in the specimen is deeply excavated in the usual manner and contains the crown of a successional tooth. The latter, represented in Fig. 7, Plate XIX, is about ten lines long, and agrees in form with those ascribed to *Leiodon*.

36. A supposed pterygoid bone, previously indicated, from near Columbus, Mississippi, discovered by Dr. Wm. Spillman, together with vertebræ, a humerus, and other remains of a Mosasauroid Reptile, already described. The specimen is represented in Fig. 14, Plate XI; and I suppose it to be the greater portion of the left pterygoid. It bears some resemblance to a fragment of the lower jaw of a Lepidostoid Fish, and clearly indicates a species, if not a genus, distinct from the more familiar *Mosasaurus* of New Jersey.

The fragment is broken at both ends, though the anterior one appears to be nearly complete; and in its present state it measures three inches long. The outer border is broken, and the upper transversely convex surface, over an inch in breadth, is also mutilated. The inner border forms a narrow ledge defining the lower from the upper surface.

The specimen contains five teeth, a vacant alveolus, and portions of two others at the extremities, so that the complement of teeth appears to have accorded with that of the pterygoid series of the great *Mosasaurus*. The crowns are sustained on large osseous pedestals, as in the latter, but instead of being lodged in deep sockets they are rather arranged in a series occupying a broad groove; the fangs being coossified with each other, with the outer parapet of the bone, and the bottom of the groove, leaving the inner sides for three-fourths their length exposed.

The anterior four teeth successively increase in size, are then followed by a capacious vacant socket, and then by another tooth as large as the fourth one.

The crowns are conical, with a circular base, and are strongly curved backward. They are nearly equally divided by an acute ridge, externally and internally, which only extends about half the length of the crowns from their apex. The anterior and posterior surfaces are strongly and comparatively coarsely striated.

The crown of the first tooth is two lines long, that of the second two lines and three-fourths, of the third four lines; the others are broken at the apex. The diameter of the first at base is one line and a half; of the last tooth three lines.

The fangs of the anterior three teeth are coossified together, but are separated from that of the fourth tooth by a wide crescentoid fissure. Following the fourth tooth is a thimble-like socket half an inch deep at its outer wall, and five lines wide. The fangs of the second, fourth, and last teeth present excavations at their inner part posteriorly for the accommodation of successors.

Among the many specimens of teeth which have been indicated and described, it may be noticed that there are a number of well-marked varieties of form which might be viewed as representing different genera and species of *Mosasauroids*, were it not that through intermediate forms they more or less graduate into one another. Referring to the plates IX, X, XI, in which nearly all the varieties of teeth have been figured, the gradation of form can readily be traced. If most of the specimens belong to the same species, the variation of form is certainly remarkable; but on the other hand, if the well-marked varieties of form be considered as indicating distinct species, then the number of these is far greater than any one had suspected.

a. The specimens described under Numbers 1, 3, 4, 5, 7, 8, 10, represented in Figs. 1, 2, 3, Plate IX; Figs. 1, 2, 3, Plate X, exhibit teeth answering to the usual description of authors as characteristic of the great *Mosasaurus*. The crown, long, conical, curved especially towards the apex, and unequally divided by a pair of acute ridges into two surfaces, of which the inner is the more extensive and convex, and both are subdivided into narrow planes. The specimens present a wide range in size, and differ in the relative extent of their two surfaces, and in the number and distinctness of their subdivisional planes.

b. Number 9 resembles those intermediate in size of the foregoing, but has the crown more compressed and less unequally divided by the acute ridges.

c. Number 6, Fig. 6, Plate X, resembles the larger specimens of *a*, but has the crown somewhat compressed, is less unequally divided by the acute ridges, has more numerous subdivisional planes but less distinct, and it is striated.

d. The eight large specimens of Number 14, most of which are represented in Figs. 5, 6, Plate IX; Figs. 7–10, Plate X, resemble the larger ones of *a*, but the crowns are nearly or quite equally divided by the acute ridges. In several the crown is nearly as full as in *a*, but in others is compressed; and in one specimen Fig. 4, Plate X, there is but a single acute ridge to the crown. The ninth tooth of the series Number 14, Fig. 5, Plate XI, supposed to have belonged to the same individual, is a miniature form of the specimen just indicated with a single acute ridge, except that it is destitute of subdivisional planes.

e. Numbers 11, 12, 13, the smaller specimen of Number 18, and Numbers 19 and 31, Figs. 4, 8, 10, Plate IX; Figs. 5, 11, Plate X, and Figs. 9, 12, Plate XI, exhibit crowns of teeth having nearly the form of those of *a*, but totally devoid of subdivisional planes. They present a great range of size, and vary in the relative extent of their inner and outer surfaces.

f. Number 15 resembles the large specimen of *d*, Fig. 4, Plate X, which has a single acute ridge, but it is almost destitute of subdivisional planes.

g. Numbers 16, 17, and the large specimen of Number 18, Figs. 7, 9, 11, Plate IX, have crowns like the more compressed ones of *d*, but are totally destitute of subdivisional planes, and one of the specimens has but a single acute ridge as in *f.*

h. Numbers 20, 22, 23, 35, Figs. 1–4, 10, Plate XI; Fig. 7, Plate XIX, have crowns like the preceding *g*, and the small one of *d*.

i. Number 21, Figs. 6, 7, Plate XI, has the crowns as in the preceding, but strongly striated, and with a disposition to form subdivisional planes.

j. Numbers 24, 28, 29, Fig. 11, Plate XI, have crowns intermediate in character with the more compressed ones with subdivisional planes of *d*, and the two ridged ones of *g* without subdivisional planes.

k. Numbers 25, 26, 27, Figs. 12, 13, Plate X, have compressed crowns, nearly equally divided by acute ridges, and with the surfaces subdivided into planes, like the compressed crowns of *d*, but they are smaller.

l. Number 30, Figs. 14, 15, Plate X, have demiconoidal crowns, with the inner surface of less extent and convexity than the outer, the reverse condition usually observed in *Mosasaurus*. They perhaps indicate a different genus from the true *Mosasaurus*.

m. Numbers 32, 33, 34, Figs. 16, 17, 18, 19, Plate X, are small forms intermediate to those of *e* and *k*.

n. Number 36, Fig. 14, Plate XI, exhibits teeth with crowns decidedly peculiar.

MACROSAURUS.

Macrosaurus lævis.

Macrosaurus lævis, Owen, Jour. Geo. Soc., Lond. 1849, V, 380.
Macrosaurus, Emmons, Report North Carolina Geol. Sur., 1858, 213, Fig. 34 *a*.

In the Proceedings of the Geological Society of London, Prof. Owen describes two vertebræ, forming part of a collection of fossils, from the Green-sand of New Jersey, submitted to his examination by Prof. Henry Rogers.[1] These vertebræ, Prof. Owen states, "appertain to the procœlian type, and in the degree of the anterior concavity and posterior convexity of the centrum most resemble the vertebræ of *Mosasaurus*. They are, however, longer and more slender; the character of the caudal vertebræ of the *Mosasaurus*, with their anchylosed hæmal arch, is well known and sufficiently marked. That the vertebræ in question have not formed part of a tail of a reptile, is shown by the entire absence of hypapophyses as well as hæmapophyses from the under surface of their centrum; from the side of which, however, a large transverse process, probably a parapophysis, has projected. That

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[1] Notes on Remains of Fossil Reptiles discovered by Prof. Henry Rogers, in Green-sand Formations of New Jersey. Proc. Geol. Soc. Lond., 1849, V, 380.

they had not come from the cervical or abdominal regions of the spine of the Mosasaur was satisfactorily proved by examples of vertebræ of the true *Mosasaurus Maximiliani*, from both these regions of the body, from the same deposits and locality. The difference in the forms and proportions of the vertebræ in question with corresponding ones of the *Mosasaurus* having diapophyses from the sides of the centrum, and no hypapophyses, is so great, that I cannot refer them with any probability to the same genus: they might belong to the *Mosasauroid* genus *Leiodon;* but in the absence of the confirmatory evidence of the teeth it seems preferable to refer the vertebræ in question to a new genus, which I propose to call '*Macrosaurus*,' from the length of the body indicated by the proportions of the vertebræ. I have no doubt, however, that it appertains to the *Mosasauroid* family of Lacertian Reptiles, not to the procœlian Crocodilia."[1]

The collection of the Academy of Natural Sciences contains a number of vertebræ, which appear to me to agree in character with those assigned by Prof. Owen to *Macrosaurus*, but I cannot avoid the suspicion that both the specimens in question and those described by the high authority just mentioned, really appertain to the dorsal series of *Mosasaurus.*

Figures 19, 20, Plate VII, represent one of the vertebræ referred to, from Freehold, Monmouth County, New Jersey, presented to the Academy by Mr. O. R. Willis. The body measures three inches in length, and when perfect had its posterior convexity about twenty-seven lines high and wide. From the fore part projects, on each side, a robust, conoidal, transverse process, which, when entire, has measured an inch and three-quarters in length.

Another specimen, represented in Figs. 1, 2, Plate III, is also from Monmouth County, New Jersey, and was presented to the Academy by C. C. Abbott. It probably belongs to a more anterior position of the dorsal series than the preceding, with which it agrees in the size and form of the body. The transverse processes have projected from the conjunction of the latter with the vertebral arch about the middle of the length of the body, and have been of robust proportions. The vertebral canal, preserved in the specimen, has its floor depressed towards the middle, and is seven lines high and ten wide at its entrance anteriorly.

A similar, but somewhat larger dorsal vertebra has been described and figured by Prof. Emmons, in the North Carolina Geological Survey.[2] The specimen was obtained from the Green-sand of Cape Fear River, North Carolina, and has been referred by Prof. Emmons to *Macrosaurus.*

A series of four mutilated dorsal vertebræ, agreeing in form and construction with the preceding, from Burlington County, New Jersey, were presented to the Academy by Mr. L. T. Germain. The first has its body two inches and a half long, the others are slightly less. The first, when perfect, has had its posterior convexity about twenty-one lines in diameter; a second, which did not immediately follow the former, had its convexity about twenty-three lines wide, and nineteen high; and

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[1] Notes on Remains of Fossil Reptiles discovered by Prof. Henry Rogers, in Green-sand Formations of New Jersey. Proc. Geol. Soc. Lond., 1849, V, 381, Plate XI, Figs. 1–6.

[2] P. 213, Fig. 34, *a.*

a third has its convexity two inches wide, and twenty-one lines high. The spinal canal, preserved in two of the specimens, has a semi-circular form in transverse section, and measures nine lines wide, and six lines high at the entrance.

POLYGONODON.

Polygonodon vetus.

Polygonodon vetus, Leidy, Proc. Acad. Nat. Sci., 1856, VIII, 221.
Polygonodon rectus, Emmons, Report North Carolina Geological Survey, 1858, 218, Fig. 37, A.; Manual of Geology, 1860, 208, Fig. 3.
Mossosaurus rectus, Emmons, North Carolina Geol. Surv., 1858, 218.

The name of *Polygonodon vetus* was founded on a remarkable specimen, consisting of a shed tooth, from the Green-sand of Burlington County, New Jersey, from whence it was obtained by Lewis T. Germain, and was loaned to me for examination by Prof. Cook. The specimen represented in Figs. 12, 13, Plate IX, consists of a nearly entire crown, worn at the apex and along the anterior and posterior borders. In construction it resembles the crown of the teeth of *Mosasaurus*, but is exceedingly narrow in comparison. It is in the form of a slender cone with the length more than three times the breadth of the base, compressed from without inwardly, and slightly curved inward and backward. It is nearly equally divided by acute ridges extending the length of the crown anteriorly and posteriorly. The ridges are much worn, so that it cannot be ascertained whether they were denticulated. The surfaces of the crown are subdivided into well-defined and slightly unequal narrow planes, there being seven externally and six internally. The enamel is quite smooth, though finely fissured longitudinally and jet black in the specimen. The transverse section, as represented in the outline, No. 34, is elliptical with acute poles. The base is hollowed into a shallow funnel from a thick broken edge to a central pulp cavity, which is small, narrow, and of the shape of the crown. The interior dentine is jet black and of dense structure.

No. 34.

The length of the specimen is twenty lines; its width at base six lines by four lines and a half. The tooth may have belonged to *Discosaurus* or *Cimoliasaurus*, but the matter must be left for future determination.

A specimen, identical in form and size with that just described, was found by Prof. Emmons on Cape Fear River, North Carolina, and was probably derived from the Green-sand. It is described and figured in the North Carolina Geological Survey, page 218, Fig. 37 (A).

HADROSAURUS.

Hadrosaurus Foulkii.

Hadrosaurus Foulkii, Leidy, Proc. Acad. Nat. Sci., Phila., 1858, 218.

A remarkable reptile, of huge proportions, has been proved to have existed during the Cretaceous period of the Western Continent, to which the name of *Hadrosaurus Foulkii* has been applied.

Attention was first called to the discovery of remains of the *Hadrosaurus*, in the autumn of 1858, by W. Parker Foulke, of Philadelphia, Member of the Academy of Natural Sciences, a gentleman who has always displayed a great interest in the advancement of the objects of the latter institution. While passing the season at Haddonfield, Camden County, New Jersey, Mr. Foulke learned from one of his neighbors, John E. Hopkins, that in digging marl upon his farm, twenty years back, there had been found a number of large bones. These were said to have consisted mainly of vertebræ, and had been gradually distributed among visitors, who were curious in such objects, so that none remained in the possession of Mr. Hopkins.

In the hope of finding additional portions of the skeleton, with the permission of the latter gentleman, Mr. Foulke employed men to search in the place of the old excavation. This was situated in a narrow ravine, through which a brook flowed eastwardly into the south branch of Cooper's Creek. At the depth of nine feet from the surface the men were successful in finding numerous bones. These were imbedded in a stratum of tenacious, bluish-black, micaceous clay, in association with a multitude of shells,[1] an echinoderm,[2] several small teeth and vertebræ of fishes,[3] a coprolite, and some fossilized coniferous wood.

The bones are ebony-black, firm in texture, heavy, and strongly impregnated with ferruginous salts, especially sulphuret of iron, which often also adheres to parts in nodules and fills up interstices, foramina, and the spongy structure. They are generally well preserved, except that many are fractured, but none are water rolled, and a few specimens only appear somewhat crushed.

These osseous remains, upon which the genus *Hadrosaurus* has been founded, indicate a Reptile of equally huge proportions, and of the same habits of life, as the great *Iguanodon* of the Wealden and Cretaceous deposits of Europe; and of all living forms, though widely different, was most nearly related with the *Iguana*, *Cyclura*, and *Amblyrhynchus*.

The bones, besides a number of small uncharacteristic fragments, consist of twenty-eight vertebræ, mostly with their processes lost; a humerus, radius, and an ulna complete; an ilium and a supposed pubic bone, imperfect; a femur and tibia

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[1] According to Dr. Isaac Lea (Proc. Acad. Nat. Sci., 1861, 150) the shells consisted of *Arca Enfaulensis, A. Saffordi, Astarte crenulirata, A. octolirata, Anomia tellinoides? A. argentaria, Cardium multiradiatum, C. Enfaulense, Cardita subquadrata, Corbula subcompressa, C. crassiplicata, C. Foulkei, Crassatella lintea, Ctenoides crenulicostata, Dosinia depressa, D. Haddonfieldensis, Dentalium Enfaulensis, Exogyra costata, Gervilia ensiformis, Inoceramus involutus, Leda protexta, L. longifrons, Linaria metastriata, Legumen apressus, L. ellipticus, Modiola Juliæ, Nucula percrassa, Ostrea denticulifera, O. larva, O. plumosa, O. tecticosta, Pecten simplicius, Pinna laqueata, Siliquaria biplicata, Tellina (Tellinimera) eborea, Trigonia Enfaulensis, Lunatia paludiformis, Turbonilla laqueata, Turritella vertebroides, T. Hardemanensis, Ammonites placenta, Scaphites iris.* The condition of these fossils is such as prove that they were deposited in a sediment completely at rest. The most tender and delicate forms remain without abrasion, and usually, in the case of the bivalve mollusks, the two valves are attached. The great tenacity of the clay, and extreme tenderness of the specimens render it almost impossible to get out perfect ones. Proc. Acad Nat. Sci., 1848, 221.

[2] *Cidares armigera.*

[3] *Odontaspis* and *Enchodus.*

complete; a fibula, with one end lost; two metatarsal bones and a phalanx, complete; two small fragments of jaws, and nine teeth.

Of the vertebræ three appear to belong to the cervical series, seven to the dorsal series, and the remaining eighteen to the caudal series.

The three mutilated cervical vertebræ, represented in Figs. 1, 2, 3, Plate XII, are from the middle or posterior part of the series. Their body is provided with a hemispherical articular convexity in front, and a corresponding concavity behind. The outline of the articular end is hexahedral. The articular convexity is somewhat flattened at the summit, which slopes upward. The lateral borders of the convexity expand and unite below in a broad lip. The sides of the body, at their fore part above the middle, are furnished with a tuberosity, or inferior transverse process, terminated by a concave, roughened facet for articulation with a cervical rib. Below the process the side of the body is concave longitudinally and vertically. The lower part of the body forms a broad ridge, slightly convex transversely and concave longitudinally, expanding towards the articular margins of the bone, but to the greatest degree posteriorly.

In one of the specimens, in which the vertebral arch is preserved, though devoid of its characteristic processes, the spinal foramen is seen to be of large size and nearly circular; measuring sixteen lines high and eighteen lines wide.

The length of the body, in the most perfect specimen, measures at the side about two inches and a half. The same specimen from the bottom of its articular concavity to the summit of the corresponding convexity measures thirty-two lines. The depth of the articular concavity is about thirteen lines; the prominence of the anterior convexity is seventeen lines from the lateral border of its base.

The extreme height and width of the body of a second specimen, which possessed about the same length as the former, measures at the base of the articular convexity about thirty-eight lines. The breadth of the abutment of the vertebral arch in the same specimen is nineteen lines.

A dorsal vertebra, represented in Figs. 4, 4, *a*, Plate XII, from the anterior part of the series, has its body convexo-concave as in the cervical specimens. The length of the body laterally is about three inches; its height and width anteriorly thirty-four lines. The articular ends are cordiform in outline. The anterior articular convexity is nearly as prominent as in the cervical vertebræ, but the corresponding posterior concavity (Fig. 4, *a*) appears less deep, from the borders being bevelled off outwardly.

The sides of the body are longitudinally concave, and meet below in a saddle-like ridge expanding in front and behind.

The sides of the vertebral arch, at their forepart, exhibit a vertically elliptical concave facet for articulation with the head of a rib. The abutment of the arch measures twenty-three lines wide. The spinal foramen is subcordate, widest above, and measures fifteen lines in height and width.

Four dorsal vertebræ, represented in Figs. 5–8, Plate XII, from the middle of the series, have their body ot the same form as the specimen just described, but the extremities exhibit a less prominent convexity in front, and a shallower concavity behind. They vary a little in size, and slightly in other characters. Their body, measured at the side, averages about three inches and a half in length, and below is slightly shorter. In front they measure about thirty-eight lines in height, and forty lines in width. The articular ends have the same outline as in the former specimen.

The articular convexity of the more anterior pair of specimens, Figs. 5, 6, which are slightly longer than the others, is irregular, presenting the appearance of an expanded mass that has collapsed. In the succeeding pair of specimens, Figs. 7, 8, the articular convexity is more uniform, and is defined from the lower border of the body by a crescentoid lip prolonged below. The border of the articular concavities, in the four specimens, is bevelled off and prolonged inferiorly.

The spinal foramen is subcordate. In the anterior pair of specimens it is about fifteen lines in height and width; in the posterior pair about fourteen lines in height and width.

The articular facet for the head of the rib is observed in the four specimens to rise successively higher on the sides of the vertebral arch, and as in the former specimen described, it is a vertically elliptical concavity. From the relative position of these articular facets, the four vertebræ have been placed in the succession designated, otherwise I should have been induced to place the hinder pair in advance from the more uniform anterior convexity of their body, and their slightly less length.

In the posterior pair of specimens, Figs. 7, 8, the articular processes of the arch are preserved, and in one of them part of the spinous process. The length of the vertebræ between the anterior and posterior articular processes is five inches and a half. The processes are elliptical planes with their long diameter nearly parallel with the axis of the vertebræ. Those anterior look towards each other with a slight inclination upward; those posterior of course have an opposite direction.

A transverse process, on the right side of the specimen, Fig. 7, apparently unbroken, is of robust proportions, extends outwardly, backward, and upward, and terminates in a rounded end without enlargement.

Two posterior dorsal vertebræ, represented in Figs. 9–11, Plate II, have the same general form of body as those just described. It is, however, shorter, but broader and deeper. Thus the smaller of the two specimens has the extreme length of the body at the sides forty-one lines; the width and depth anteriorly forty-five lines. The larger specimen has its body forty lines long, and four inches wide and deep anteriorly. The sides of the body, as in the preceding vertebræ, are longitudinally concave, and terminate below in a rather sharp saddle-like ridge expanding towards the articular borders.

The articular ends, Fig. 11, are cordiform in outline, with the lateral and inferior borders strongly everted and convex. The posterior end is moderately concave with wide everted margins. The depth of the concavity at its centre is about five lines. The anterior articular end, Fig. 11, presents a crescentoid depressed or sub-concave surface below, including a sub-convex prominence extending from the centre to the upper border of the articular surface.

The spinal foramen is cordiform, rather wider than high, being about fifteen lines transversely, and thirteen vertically. The abutments of the vertebral arch are twenty seven lines wide, and present no mark for the head of a rib. The latter, however, appears to have been situated higher, exterior to the upper back part of the position of the anterior articular processes, which are rather wider apart than those of the preceding vertebræ.

No lumbar vertebræ or portions of a sacrum were discovered with the collection of *Hadrosaurus* remains under examination.

Eighteen caudal vertebræ, probably less than half of the original number, form part of the collection. In all of them the body is moderately biconcave; the concavities being of nearly equal depth. The borders of the articular surfaces are strongly everted, convex, and prolonged below into pairs of robust, sloping abutments for the articulation of chevron bones. The sides of the body are concave longitudinally, convex vertically, and are defined below by obtuse ridges, extending between the anterior and posterior chevron abutments. The under surface of the body forms a concavity with a square outline whose angles are produced by the abutments just mentioned. The articular ends are hexahedral in outline.

Three vertebræ, of which two are represented in Figs. 9, 10, Plate XII, from the commencement of the caudal series, are remarkable for their diminution in length and great increase of breadth and depth, in comparison with the dorsal and cervical vertebræ. Their body averages thirty-one lines in length, and in the three specimens ranges from five inches and a half to six in breadth by about five inches and a quarter in depth. They appear to have been provided with strong transverse processes, as the broken roots of these extend from about the middle of the body to the conjunction of the latter with the vertebral arch. The spinal foramen is transversely oval, about nine lines in depth and fourteen in width. The breadth of the abutments of the vertebral arch is about fifteen lines.

The articular processes have subcircular flat facets, those in front being directed obliquely towards each other, those behind looking obliquely outward and downward. The anterior ones project a little in advance of the line of the front articular surface of the body; the posterior ones overhang the back articular surface.

The ten succeeding specimens of caudal vertebræ, of which six are represented in Figs. 11–16, Plate XII, exhibit a gradual but slight increase in length until they almost equal in this respect the posterior dorsals above described, and they undergo a gradual diminution in depth and width. The body of the eighth specimen in the series under consideration is about equal in bulk to that of the posterior dorsals above described; those in advance are larger, those behind are smaller.

The first (Fig. 11) of the ten specimens has its body thirty-three lines long, sixty-one broad, and fifty-four deep; the sixth specimen has the body thirty-six lines long, and fifty-one lines broad and deep; and the tenth (Fig. 16) has its body thirty-eight lines long, and forty-three lines broad and deep.

In succession, the abutments of the chevron bones become more distinctly defined on each side by an intervening notch, which, however, at no time extends to their base.

The spinal foramen undergoes a gradual diminution in capacity and assumes a more circular form. In the second specimen of the series it is nine lines deep and twelve wide; in the tenth it is eight lines deep and wide.

The abutments of the vertebral arch present a slight successive increase in width. In the first specimen it is twenty lines wide; in the tenth specimen twenty-two lines.

The articular processes are like those of the preceding caudal vertebræ, and successively increase their distance apart Thus in the second specimen of the series under consideration the space reaching from those anterior to the ones posterior measures forty-six lines; in the third specimen the same space occupies forty-eight lines; and in the tenth, fifty lines.

The spinous process, preserved entire in the third specimen (Fig. 13), is eight inches and a half long. Directed upward and backward it is at first cylindrical, but approaching its free extremity becomes laterally compressed. Judging from the remains of this process in the other caudal vertebræ, it has had a similar form throughout.

The transverse processes are apparently all broken or bruised at the ends in the vertebræ in which they have existed. In the six specimens in advance they appear to have been formed as distinct elements, and were apparently coossified by a broadly expanded root to the conjunction of the vertebral body and arch. In the anterior two specimens (Figs. 11, 12) they appear to have been short, robust prominences, with their root extending nearly as far down as the middle of the side of the body. In the succeeding three (Fig. 13) specimens the processes appear to have been short, obtuse prominences, not reaching by their expanded root below the upper third of the side of the body. In the next three of the series, as seen in Figs. 14, 15, the transverse processes are obsolete, or appear as a slight, roughened prominence, at or below the union of the vertebral body and arch. In the last specimen no trace of the process appears, as seen in Fig. 16.

The remaining five caudal vertebræ of the collection, of which the back four are represented in Figs. 17–20, possess the same general form of the body as in the preceding specimens, and exhibit a successive diminution of depth and breadth in relation with the length, which also undergoes a moderate reduction. Thus in the first of the specimens the body is nearly of equal length, depth, and width, their measurements being about three inches. The body of the succeeding three specimens (Figs. 17–19), which are nearly equal in size, is thirty-three lines long, twenty-eight wide, and twenty-five deep. The last specimen (Fig. 20) has its body thirty lines long, and twenty-one wide and deep.

In the first of this series the spinal canal is vertically oval, eight lines high, and six wide; in the fourth specimen it is subcircular, five lines and a half wide and high.

The abutments of the vertebral arch in the first specimen are twenty lines wide; in the fourth specimen, thirteen lines.

Transverse processes appear not to have existed in these five caudal vertebræ, as no trace of them is visible. The vertebral arch in all is too much mutilated to ascertain whether it was provided with articular and transverse processes.

All the vertebræ I have described appear to be fully grown, their arch being firmly coossified with the body. The sutural conjunction between the two arts occupies a broad elliptical space, the outline of which is distinctly evident, extending between the prominent borders of the articular faces of the body.

The ossific structure of the vertebræ is coarse, and the articular surfaces of the bodies are rather uneven and roughened. The specimens generally present no conspicuous vascular foramina, and only a few of them exhibit one or two moderate sized orifices of this kind at the lower part of the body.

From the description of the vertebræ it may be perceived that they increase in size to the posterior part of the dorsal series. In comparison with the latter the anterior caudal vertebræ undergo a great increase in breadth and depth, but decrease in length. Subsequently the caudals gradually diminish in depth and breadth, but increase in length to near the end of the tail, where they again slightly decrease in the latter direction.

In the cervical series of vertebræ the bodies are prominently convex in front, and in a corresponding degree concave behind. These conditions are maintained in the anterior of the dorsal series, but subsequently the convexity is depressed and the concavity becomes more shallow, and even the posterior dorsals have assumed a moderately biconcave character. In the caudal series the vertebral bodies are decidedly biconcave throughout.

The transverse processes of the anterior caudal vertebræ appear to have been of robust proportions, but rapidly declined in the series, and ceased to exist altogether in the posterior caudals.

The specimen of an anterior caudal above described, in which the spinous process has been preserved entire, may serve to guide us in attempting to estimate the depth and breadth of the tail of *Hadrosaurus*. The vertebra I suppose to be the seventh or eighth caudal, and if we assume that it possessed a chevron bone of half the length of the vertebral arch together with its spinous process, the tail in the position of this vertebra would have measured about a foot and a half in depth, and about eight inches in thickness. Such a form of tail, though admirably adapted to swimming, would, however, not be incompatible with terrestrial habits, as we observe in the living *Iguana* and *Cyclura*.

The vertebræ of *Hadrosaurus* bear a near resemblance to those referred to the *Iguanodon* by Drs. Mantell and Melville.[1] In both genera the cervical series are convexo-concave, which character is retained in a less degree in the anterior dorsal vertebræ. In *Iguanodon*, according to the authors just mentioned, the posterior dorsal and anterior caudal vertebræ are plano-concave, which may likewise be the case in the corresponding bones of the *Hadrosaurus*, but in the specimens under examination, the anterior articular surface of the bodies is slightly depressed, so that the posterior dorsals and anterior caudals of *Hadrosaurus* are described as biconcave. In both genera the posterior caudals are biconcave.

Prof. Owen says: "Both articular ends of the vertebræ of the *Iguanodon* are nearly flat, thereby differing more from the concavo-convex vertebræ of the *Iguana* than those of any of the existing Crocodiles or Lizards do."[2] According to this

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[1] Addit. Obs. on the Osteol. of the Iguanodon, &c. Phil. Trans. Roy. Soc., Lond., 1849, p. 271

[2] British Fossil Reptiles, Pt. VI, Dinosauria, p. 324.

general character ascribed to the vertebræ of *Iguanodon*, those of *Hadrosaurus* are totally different.

The convexo-concave vertebræ attributed to the cervical series of *Iguanodon* by Drs. Mantell and Melville, are referred by Prof. Owen to a Crocodile under the name of *Streptospondylus major*.[1] Other vertebræ attributed to the posterior dorsal or lumbar and to the caudal series, by Drs. Mantell and Melville, are referred by Prof. Owen to two additional crocodilian Reptiles under the names of *Cetiosaurus brevis* and *C. brachyurus*.[2]

No portions of the skull of *Hadrosaurus* were discovered except some small fragments of the jaws, represented in Figs. 24–26, Plate XIII. One of these, a portion of the lower jaw, much mutilated externally, Fig. 25, exhibits on its inner aspect, Fig. 24, a series of longitudinal alveolar grooves separated by narrow intervening ridges. The other, apparently a portion of the upper jaw, Fig. 26, exhibits similar grooves, but these are bent at an obtuse angle about the upper third of their course.

As previously mentioned, in association with the bones of *Hadrosaurus Foulkii*, there were discovered nine teeth, which above all other parts tended to determine the relationship of the fossils. The teeth are so small in comparison with what one would expect to find in company with the other remains, that had they been discovered alone, they would perhaps not have been suspected of belonging to *Hadrosaurus*. They present the same general conformation and peculiarity of structure as those of the *Iguanodon*, indicating, as in the latter, a vegetable feeding Reptile, one which masticated its food like the herbivorous Mammalia.[3] Although among

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[1] Report Brit. Assoc., 1841, p. 91.

[2] Ibidem, p. 94, 100.

[3] Dr. Mantell, in his work entitled "Petrifactions and their Teachings," p. 228, in an article on the discovery of the *Iguanodon*, gives the following account: "Soon after my first discovery of bones of colossal reptiles in the strata of Tilgate Forest, some teeth of a very remarkable character particularly excited my curiosity, for they were wholly unlike any that had previously come under my observation. The first specimen that arrested my attention was a large tooth, which from the worn, smooth, and oblique surface of the crown had evidently belonged to an herbivorous animal, and so entirely resembled in form the corresponding part of an incisor of a large pachyderm ground down by use, that I was much embarrassed to account for its presence in such ancient strata, in which, according to all geological experience, no fossil remains of mammalia would ever be discovered; and as no known existing reptiles are capable of masticating their food, I could not venture to assign the tooth in question to a Saurian."

Dr. Mantell states that "through Mr. Lyell, who was about to visit Paris, he availed himself of the opportunity of submitting the tooth to the examination of Cuvier, who, without hesitation, pronounced it to be an upper incisor of a Rhinoceros." This mistake, under the circumstances, was not surprising, as the worn teeth of *Iguanodon* actually resemble the incisors of the Rhinoceros more than they do the teeth of any other known animal, and at the time of the determination no reptiles were known with teeth adapted to the mastication of vegetable food.

Cuvier, in the Ossemens Fossiles, Ed. 4, T 10, 199, in reference to the teeth of the *Iguanodon*, says that "they may possibly belong to a Saurian, but one more extraordinary than any other known. The peculiarity of the teeth consists in their having been worn away as in herbivorous mammals, so that when I first saw a specimen which was much worn, I did not doubt that it was derived from a mammal." He adds, that "it was only after M. Mantell had sent him a series of specimens worn and unworn that he became entirely convinced of his error."

Dr. Mantell further remarks that "he had previously submitted the tooth and some other specimens to the Geological Society of London, where they were generally viewed as belonging to some large living Reptiles there are vegetable feeders, such as the *Iguana* and *Amblyrhynchus*, yet the teeth of these with their trenchant jagged borders, are adapted to lacerating or sawing instead of masticating the food.

Several of the teeth of *Hadrosaurus* are nearly identical in form and details of structure with the specimen of a tooth discovered a short time previously to the former, by Dr. F. V. Hayden, in the Bad Lands of the Judith River. The tooth just mentioned, together with several other much worn specimens, I referred to a distinct genus under the name of *Trachodon*, but I shall not be surprised to learn that future discovery determined *Hadrosaurus* and *Trachodon* to be the same.[1]

Of the nine specimens of teeth preserved among the collection of remains of *Hadrosaurus*, seven are alike in form, and are supposed to have belonged to the lower jaw; the other two, different from the former, are supposed to have belonged to the upper jaw.

The teeth of *Hadrosaurus* were probably inserted in the jaws in the same manner as Dr. Mantell supposed to be the case in the *Iguanodon*, that is to say, with the enamelled surfaces of the crowns of the upper teeth directed outward, and of the lower teeth inward; an arrangement, as remarked by Dr. Mantell, which finds an analogy in the reversed position of the molar teeth of ruminating animals.

The shape and markings of the teeth of *Hadrosaurus* appear to indicate that they were placed in much closer apposition with one another and their successors than in *Iguanodon;* the arrangement in the former being very remarkable. In *Iguanodon* the teeth occupying a position in the functional series were succeeded by others

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fish, or as mammalian teeth from a diluvial deposit, and Dr. Wollaston alone supported him in the opinion that he had discovered the teeth of an unknown herbivorous reptile." Finally, he adds, "it was not until I had collected a series of specimens, exhibiting teeth in various states of maturity and detrition, that the correctness of my opinion was admitted either as to the character of the dental organs or their geological position."

[1] The teeth referred to Trachodon were discovered by Dr. Hayden, in an estuary, fresh water deposit, which he calls the Bad Lands of the Judith River, situated on the upper Missouri River, near its source. In regard to the age of the deposit, the testimony derived from the fossils is of a conflicting character, but according to Dr. Hayden, the facts warrant the opinion that if the deposit is not an American representative of the Wealden of Europe, it is at least in part as old as the Cretaceous. Proc. Acad. Nat. Sci., Phil., 1856, p. 72. Trans. Am. Phil. Soc., Phil., 1859, p. 123.

Among the collection of fossils, brought by Dr. Hayden from Western America, were several vertebræ and a phalanx, which I have referred to a Dinosaurian with the name of *Thespesius.* The specimens were obtained from the Great Lignite formation of Grand River, Nebraska, which Dr. Hayden considers to belong to the Miocene Tertiary period. The phalanx mentioned nearly corresponds in form and size with the proximal phalanx of the hind foot of *Hadrosaurus*, described in the preceding pages. Of the vertebræ, the two larger specimens are anterior caudals, and are convexo-concave; the small one, a posterior caudal, is plano-concave. Had the remains of *Thespesius* and *Trachodon* been found in a deposit of the same age, I should have unhesitatingly referred them to the same animal, and I cannot avoid the suspicion that future investigation may determine them to be the same. Should such a determination prove to be the case, the minor details of structure of the tooth of *Trachodon* different from those of *Hadrosaurus*, together with the convexo-concave anterior caudals and the plano-concave posterior caudal of *Thespesius*, in comparison with the biconcave caudals of *Hadrosaurus*, will be sufficient to separate generically the New Jersey Dinosaurian from that of the Upper Missouri. For an account of *Thespesius* see Proc. Acad. Nat. Sci., Phil., 1856, p. 311, and Trans. Am. Phil. Soc., 1859, p. 151.

in the same manner as in living Lacertians. In *Hadrosaurus* the shape of the teeth and their markings make it appear as if they were closely crowded, the functional and successional series together, so as to produce a vertical quincuncial arrangement, as represented in the partially ideal Fig. 19, Plate XIII.

The specimens of inferior teeth vary slightly in size, and present different conditions, from one that is unworn, to another which has its crown half worn away.

An unworn and almost perfect specimen, represented in Figs. 1–4, Plate XIII, is twenty-two lines in length. Viewed laterally, Figs. 3, 4, in outline it has the form of an obtuse angled triangle, of which the two shorter sides correspond with the division of the tooth into crown and fang.

The crown, separately considered, is trihedral or demiconoidal, and bevelled off on each side towards the base internally, and it comprises rather more than half the length of the tooth. It widens antero-posteriorly from the summit to the middle, and then decreases in the same direction towards the fang. In the reverse direction, it increases in breadth from the summit to the bottom of the crown.

The inner side of the crown, Fig. 1, *a*, is alone invested with enamel, and forms a lozenge-shaped surface divided in its length by a prominent median carina. It is slightly convex vertically, and has the borders a little everted, so that the divisions of the surface on each side of the carina are slightly concave transversely. The upper angle, constituting the apex of the tooth, is rounded, the lateral angles are obtuse, and the lower angle is notched.

The upper borders of the enamelled surface are thickened, rounded, and furnished with a series of feeble transverse ridges resolved into minute tubercles, as represented in the magnified view of Fig. *d*.

The outer surface of the crown, Fig. 2, has a dull aspect; at its upper half is paraboloid in transverse section, but below is ellipsoidal. The lower half presents at the sides internally a bevelled triangular plane, extending upon the fang and marked by vascular grooves, as seen in Figs. 3, 4, *c*. One of the bevelled planes, Fig. 4, *c*, next the enamel edge, is marked by a series of impressions, adapted to the accommodation of the tubercular enamel border of the contiguous side of the crown of a lateral successional tooth. The opposite plane is devoid of this series of impressions, as seen in Fig. 3, *c*.

Evidently it appears from the shape and markings of the bevelled planes just described that they were adapted to fit the summits of the crowns of lateral successional teeth, according to the plan represented in Fig. 19.

In the slightly oblique relationship of the functional and successional teeth the tuberculated enamel border of one side of the latter overlapped the contiguous lower border of the former in front, while the opposite tuberculated enamel border of the successional teeth was overlapped by the contiguous lower border of the functional teeth behind. Hence one bevelled surface presents the impression of the tuberculated enamel border of a successional tooth, and the opposite surface does not. The vascular grooves of the bevelled surfaces are due to the vessels in the membrane separating the successional from the functional teeth.

The fang is laterally compressed, conoidal, and rather shorter than the crown, of which it is an extension without the enamel. Its outer border continues the slope of the corresponding border of the crown, and forms with it a convex ridge extending the whole length of the tooth. Its inner border forms an obtuse angle from the bottom of the enamelled face of the crown, and is excavated into a shallow groove marked by vascular furrows. The grooved border appears to have been adapted to fit the outer border of the crown of a successional tooth beneath.

The measurements of the tooth are as follows:—

	Lines.
Length of the tooth externally	22
Length of enamelled crown internally	14
Breadth of enamelled crown internally at middle	5¾
Breadth of enamelled crown internally at bottom	2
Width of crown at base from without inwardly	7½
Length of fang internally	12½

The tooth just described bears a near resemblance to one of those, before alluded to, upon which the genus *Trachodon* was founded, as may be seen by comparing the figures of the former (1–4, Plate XIII) with those of the latter (12–14, Plate II). The specimen of the tooth of *Trachodon* has lost its fang, but its crown has the same form as that of *Hadrosaurus*, and nearly the same size, except that towards the base it is narrower from without inwardly, and wider in the opposite direction. In the tooth referred to *Hadrosaurus* the diameter at base, from without inwardly, is twice as great as that from side to side, but in that of *Trachodon* it is only a fourth greater, while in both the crown is of nearly equal length.

The outer portion of the crown of the tooth of *Trachodon* is irregularly roughened with a multitude of granulations or minute tubercles, and, independently of the triangular bevelled planes at its base, is subdivided by ridges into three surfaces, of which those lateral are flat, or even slightly depressed at the upper part, and the intermediate one is moderately convex. In transverse section the outer portion of the crown forms three sides of a hexagon. In *Hadrosaurus* the outer portion of the crown is smooth, and forms the two sides of the vertical section of a cone with a rounded apex.

The upper enamel borders of the tooth of *Trachodon* are devoid of the characteristic groups of tubercles observed in the tooth of *Hadrosaurus*, though they exhibit a feeble tendency to development in a slight irregularity of the limit of the border where it is defined from the dentinal structure of the outer portion of the crown, and by a slight unevenness of the borders of the apex.

Since writing the present memoir I have seen a "Supplement to the Fossil Reptilia of the Cretaceous Formations," by Prof. Owen, in the publications of the Palæontographical Society for 1860. At the end of the Supplement, Prof. Owen indicates a tooth, from the upper Green-sand, near Cambridge, England, as that of a young *Iguanodon*, which bears a near resemblance to those above described of *Hadrosaurus* and *Trachodon*. It is represented in Figs. 15, 16, Plate VII, of the Supplement, and though closely related in character with the teeth of the *Iguanodon Mantelli*, certainly differs from all those which had been previously referred to this species. The specimen has nearly the form and size as those of *Hadrosaurus* and *Trachodon*, but judging from Fig. 15 it differs in the upper borders of the crown, being broken into a series of minute imbricating laminæ. Perhaps the three teeth alluded to, so like one another, and referred to *Hadrosaurus*, *Trachodon*, and *Iguanodon*, represent three species of a genus allied to, but quite distinct from the true *Iguanodon* of which the *I. Mantelli* is the type.

Figs. 5–9, Plate XIII, represent two specimens of inferior teeth of *Hadrosaurus*, the forms of which agree with that already described. In one (Figs. 5, 6, 7) the crown is half worn away, exhibiting the triturating surface as a shield-like, inclined plane, very slightly depressed, bordered by enamel at the inner bow-like border, and feebly roughened by a linear crucial ridge, the limbs of which give off diverging branches. In the other specimen (Figs. 8, 9) the apex is worn off so as to present a small shield-like triturating surface, which is smooth or devoid of a crucial ridge traversing it.

Of the two teeth of *Hadrosaurus*, supposed to have belonged to the upper jaw, one is an unworn crown, and is represented in Figs. 10–13, Plate XIII; while the other is the crown of a smaller tooth, with its apex worn off, and retaining part of the fang, and is represented in Figs. 14–17.

The superior unworn crown, in comparison with that of the inferior tooth, presents a rather demi-ovoidal than a demi-conoidal form, but differs further from the comparatively enormous degree of projection of its carina.

The lozenge-shaped enamel surface, Fig. 10, which is to be viewed as the external one, or the reverse in position of that of the inferior teeth, is wider at the two extremities and slightly narrower at the middle than in the latter. It extends outwardly upon a carina, which starts from the apex of the crown, and gradually increases in depth until it nearly equals half the diameter of the tooth from without inwardly. The apex of the crown is much more blunt than in the lower tooth, and the bottom of the enamel surface forms two sides of a triangle, the apex of which is the bottom of the edge of the carina. The lateral angles are also more obtuse than in the lower teeth. The groups of tubercles ornamenting the lower borders of the crown, especially approaching the apex, are also somewhat larger.

The inner portion of the crown (Figs. 11, 15) is subdivided into four planes, of which the intermediate pair extend from the apex to the base, while those on each side extend from the apex to near the position of the lateral angles of the crown.

The basal half of the crown on each side presents a somewhat depressed ellipsoidal surface, with a narrow prolongation extending upon the fang (Figs. 12, 13, 16, 17, *a*), corresponding with the triangular bevelled planes of the inferior teeth, and like them exhibiting marks as if they had been adapted to fit or come into contact with lateral successional teeth. Unlike, however, those of the inferior teeth, these surfaces of the superior teeth exhibit on both sides the series of impressions induced by the tuberculated borders of the crowns of the successional teeth. Between these lateral surfaces of contact with the latter, the base of the crown is excavated, forming a narrow depressed tract (Figs. 11, 15, 17, *b*), continuous with a wide shallow groove of the fang, adapted to fit the apex and outer part of the summit of the crown of a successional tooth from above.

The fang of the superior teeth appears from the specimens to have been proportionately narrower than in the inferior teeth, and further appears mainly to spring from the enamelled portion of the crown instead of the opposed portion as in the inferior teeth. At its connection with the crown it is pentahedral in section with the two outer sides corresponding with the sides of the carina of the latter.

The measurements of the unworn upper tooth are as follows:—

	Lines.
Length of the crown	13½
Breadth at the lateral angles	5½
Breadth at bottom	3½
Greatest diameter from within outwardly or from the prominence of the bottom of the crown internally to the edge of the carina externally	8
Diameter of fang at its connection with the crown transversely	3½
Diameter of fang from within outwardly	4

The specimens of inferior teeth appear to be nearly solid, that is to say, their pulp cavity is almost obliterated, as a portion remains pervious only for a short distance within the fangs. In one of the specimens, in which the fang is broken off near its conjunction with the crown, the remains of the pulp cavity form a linear suture extending through the middle half of the diameter from within outwardly. The sides of the pulp cavity, where visible, are exceedingly rough and pitted, the pits corresponding with a multitude of minute offsets diverging from the main cavity into the dentine.

As the teeth of *Hadrosaurus* were worn away from attrition to which they were subjected, a flat, or very feebly depressed, oblique triturating surface was produced and gradually increased in breadth to the middle of the crown, and then as gradually decreased to the fang, upon which it was also continued until this became worn out. The triturating surface of the crown exhibits a shield-shaped plane of dentine bounded in the upper teeth externally by a bow-like border of enamel; in the lower teeth bounded in the same manner internally.

The series of teeth at the border of the jaw in functional position appear to have formed a continuous sloping pavement, presenting triturating points and facets of different sizes and of several patterns, according to the portions of the teeth which had reached the triturating surface, as represented in the partially ideal Fig. 18, Plate XIII. In the upper jaw the slope of the dental pavement was directed downward and inward, and was margined externally by a festooned cutting edge of enamel, as seen in Fig. 18, *d*. In the lower jaw the arrangement was reversed, the dental pavement being parallel with the former and slanting with a direction outward and upward, and the festooned cutting edge of enamel being internal, as seen in Fig. 19, *a*, *b*.

The intimate structure of the teeth of *Hadrosaurus*, as viewed by the microscope, is exhibited in Fig. 1, Plate XX, representing the transverse section of the crown of an inferior tooth above its middle. The representation is not to be viewed as exact, as the proportions of the whole section and the elements of structure, for obvious reasons, have not been preserved. It is rather a diagram exhibiting the relative position of the structural elements in the transverse section of the crown of a tooth.

The section is mainly composed of hard dentine in which the dentinal tubules emanate from a median crucial line and radiate towards the periphery. The crucial line corresponds with that previously mentioned as visible on the triturating surface of the teeth, and is to be viewed as the remains of the pulp cavity. It is pervaded with vascular canals, the cut orifices of which may be seen in the section.

The dentinal tubules pursue a gently undulating nearly parallel course, and the successive waves in the section, when viewed by transmitted light, appear alternately darker and lighter, giving rise to the impression of a concentric laminar arrangement of the dentinal structure. The tubules are exceedingly fine and arranged very closely together. They branch in their course outwardly and measure from the $\frac{1}{15000}$th to the $\frac{1}{20000}$th of an inch.

The inner surface of the section (Fig. 1, *a*) is bordered by an enamel layer about the $\frac{1}{50}$th of an inch thick. The enamel folds around the lateral borders of the crown and ceases in a rather abrupt but thin edge. In the drawing, there is represented a section (*b*) of a narrow isolated streak of enamel, which extended a short distance along the side of the crown.

The outer border of the section (Fig. 1, *d*, Fig. 2, *b*) presents a peculiar layer, about $\frac{1}{40}$th of an inch thick, apparently consisting of a spongy reticulation of vascular tissue or vaso-dentine. It is this layer which gives the surface of the teeth, where not covered with enamel, a dull aspect; and it is friable and easily scraped off from the denser dentine within. The vascular canals of the spongy tissue are of nearly uniform size and measure about the $\frac{1}{1000}$th of an inch in diameter. From the vaso-dentine many of the vascular canals penetrate into the denser dentine, in some cases to a greater depth than the whole thickness of the former, as represented in Fig. 2, Plate XX.

The specimens of bones of the anterior extremity of *Hadrosaurus* consist of the humerus and those of the forearm of the left side.

The humerus of *Hadrosaurus*, represented in Figs. 1, 2, 3, Plate XIV, bears a near resemblance in form and proportions to that of the *Iguanodon* as figured by Dr. Mantell[1] and Prof. Owen.[2] The upper part of the shaft is twice the breadth of its thickness, is concave transversely in front, and convex behind in the same direction, and has its inner border thinner than the outer. The lower part of the shaft is cylindroid, and gradually expands towards the condyles.

The bone is broadest at its upper extremity from which the head projects posteriorly midway between two nearly equal tuberosities, which extend almost as high as the former. The head (*a*) is a hemispherical roughened prominence partly sustained by an abutment-like ridge extending downward on the back of the shaft. The upper part of the inner tuberosity (*b*) is convex and rough. The upper part of the outer tuberosity (*c*) is sigmoid and likewise rough.

From the inner tuberosity, the internal border of the shaft makes a continuous concave sweep to the lower end of the bone. From the outer tuberosity, the shaft remains expanded externally, to accommodate the attachment of the deltoid muscle, nearly to its middle (*d*), when the bone rapidly narrows to its lower cylindroid por-

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[1] Phil. Trans. Roy. Soc., Lond., 1849, Plate XXXI. Petrifactions and their Teachings, p. 286, Fig. 60.

[2] British Fossil Reptiles, Dinosauria, Plate XIX, Figs. 3–6.

tion. The border of the deltoid expansion is convex, and is roughened below for muscular attachment.

The condyles are convex and rough, and are separated in front by a notch expanding upward into a broad concavity of the shaft; behind they are separated by a wide groove extending upward and disappearing upon the shaft.

The latter, which was broken across in the specimen in two positions, exhibited a large medullary cavity.

The measurements of the bone are as follows:—

	Inches.	Lines.
Extreme length of the humerus	22	6
Breadth at the tuberosities	6	10
Thickness at the head	3	3
Breadth of shaft above the middle, or just before it begins to contract into the lower half	5	4
Thickness in the same position	2	4
Breadth of cylindroid portion of the shaft	3	2
Circumference of cylindroid portion of the shaft	9	6
Thickness of cylindroid portion of the shaft	2	9
Breadth at condyles	5	
Diameter of head	2	6
Antero-posterior diameter of inner condyle	3	6
Antero-posterior diameter of outer condyle	3	

Two orifices for medullary nutritious arteries exist on the posterior inner aspect of the bone, both being directed downward. One occupies the ridge beneath the head; the other is on the inner border of the shaft just above the middle.

The bones of the forearm of *Hadrosaurus* are not remarkably different in form from those of the living *Iguana*. No adult bones of the forearm of the congeneric *Iguanodon* have been discovered. In a slab of stone containing imbedded part of the skeleton of a young *Iguanodon*, known as the Maidstone specimen and preserved in the British Museum, there are two bones described by Dr. Mantell as metacarpals, but which are considered to be the radius and ulna by Prof. Owen, who remarks that "they offer few differences worthy of notice except their greater relative strength from the corresponding bones of the *Iguana*."[1]

The radius, Fig. 6, Pl. XIV, has a compressed cylindroid shaft elevated into a subacute ridge postero-externally for the attachment of an interosseal membrane. Its upper extremity expands into a head, with a rough margin, supporting a semicircular roughened, brachial articular surface, which is slightly concave in its longer diameter, and nearly level in the opposite direction. The lower extremity widens in a clavate manner, presents a broad groove postero-internally, and ends in a convex articular carpal surface. The measurements of the bone are as follows:—

	Inches.	Lines.
Extreme length of the radius	20	6
Circumference at middle of the shaft	5	11
Long diameter of the head	3	8
Short diameter of the head	2	6
Long diameter of carpal end	3	1
Short diameter of carpal end	2	3

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[1] British Fossil Reptiles, Dinosauria, p. 309.

The ulna, Fig. 5, Plate XIV, has a trihedral shaft becoming more cylindroid below, and has its three surfaces transversely concave above. The olecranon is an irregularly rounded prominence. The coronoid process is a thick plate of bone gradually widening from the shaft upward antero-internally. A similar but smaller process, somewhat broken in the specimen, springs from the shaft externally. The brachial articular surface slopes in a concave manner from the olecranon downward and forward, and extends between and upon the two processes below. The lower extremity of the ulna slightly enlarges in its descent, is convex externally, forms a wide and rather deep groove internally, and ends in a convex carpal articular surface. The measurements of the bone are as follows:—

	Inches.	Lines.
Extreme length of the ulna	23	3
Circumference at the middle of the shaft	7	
Greatest breadth at the coronoid process	5	
Greatest diameter of the carpal end	2	7
Short diameter of the carpal end	2	

The interior of both bones of the forearm is occupied by a coarse spongy substance.

The bones of the hinder extremities of *Hadrosaurus* are extraordinary for their huge size. In comparison with those of the fore extremities of the same animal they are of enormous proportions, exceeding in this respect not only all living Lacertians and Crocodiles, but even its extinct congener the *Iguanodon*. Thus in the Maidstone specimen of the *Iguanodon*, according to Prof. Owen,[1] the femur measures thirty-three inches long, while the humerus is nineteen inches; the tibia is thirty-one inches, and the ulna eighteen inches. In a collection of remains of the *Iguanodon*, from the Isle of Wight, according to Dr. Mantell,[2] the femur measured fifty-six inches in length, and the humerus thirty-eight inches. In *Hadrosaurus* the femur is forty-one inches and a half long, while the humerus is only twenty-two and a half, or little more than half the size of the former. The tibia is thirty-six inches and three-quarters long, and the ulna twenty-three inches and a quarter.

The femur of *Hadrosaurus*, represented in Figs. 1–6, Plate XV, is of the left side. In general form and proportions it bears considerable resemblance to the corresponding bone of the *Iguanodon*, as represented by Dr. Mantell[3] and Prof. Owen.[4] It has a quadrilateral shaft, with the head and trochanter situated on the same line as the condyles.

Externally (Fig. 2) the shaft forms a nearly flat surface vertically and transversely, and is strongly marked at the upper part and just below the middle by muscular attachments. From the posterior surface the outer is defined by a convex, though somewhat interrupted, rising of the bone, which extends from the back part of the trochanter to the corresponding part of the external condyle. The upper two-thirds of the outer surface are also defined in a similar manner from the anterior surface, but the lower third forms with the latter a more uniform convexity.

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[1] British Fossil Reptiles, Dinosauria, p. 268.

[2] Petrifactions and their Teachings, p. 301.

[3] Petrifactions, p. 292, Fig. 61.

[4] British Fossil Reptiles, Plate XX, Fig. 1.

The posterior surface of the shaft (Fig. 4), less level than the outer, presents a conspicuous process, as in the *Iguanodon*, springing from its middle internally, and calling to mind the third trochanter of certain Pachyderms, as the Horse and Rhinoceros. An abrupt rising of the bone, extending from the process just mentioned towards the head and internal condyle, defines the posterior surface from the inner one.

The internal and anterior surfaces (Figs. 1, 3), less defined from each other than the surfaces above described, together form a half section of a cylinder, which is antero-posteriorly compressed above where it sustains the head of the bone. The upper third of the anterior surface (Fig. 1) is transversely concave, arising from the presence of a strong process, springing from and defining its outer boundary. The process just mentioned, extending downward from the trochanter, gradually subsides and becomes continuous with two ridges, of which one forms the boundary between the anterior and outer surfaces of the shaft, while the other diverges in front to the lower third of the bone. The two ridges define three surfaces, giving origin to muscles corresponding with the triceps extensor of animals generally. Several inches below the commencement of the anterior ridge, to its inner side, is the orifice of a medullary nutritious canal, which is directed obliquely downward.

The head of the femur (Figs. 1–5, *a*) partially overhangs the inner part of the shaft which sustains it. Its sides are exceedingly rugged, for the most part being rendered so by numerous vertical ridges and intervening grooves (Fig. 3, *a*). The articular surface is sub-circular and only moderately convex, or, as compared with its condition in animals generally, is in a remarkable degree flattened. It is quite rough, and is rendered so chiefly by branching vascular grooves (Fig. 5, *a*), of which the main one proceeds obliquely across the head from the interval anteriorly between the latter and the trochanter.

The trochanter (Figs. 1–5, *b*), when both condyles are brought to a level, rises above the head of the bone, than which it is more convex and broader antero-posteriorly, but is narrower transversely. It is separated in front and behind from the head by wide notches. Its back part (Fig. 4, *b*) is roughened for muscular attachment. Its upper convex surface (Fig. 5, *b*) inclines inwardly, has quite an articular appearance, and is undefined from that of the head, with which it is continuous by means of an isthmus.

The condyles (Figs. 1–6, *d*, *e*), as usual, extend much more posteriorly than anteriorly. They are massive, with exceedingly rugged sides, especially that of the inner one (Fig. 3, *d*), being rendered so by vertical ridges and intervening grooves. Their convex articular surfaces (Fig. 6) are conjoined by a narrow isthmus, and are likewise rugged.

In the absence of a well-developed patella, as in the recent *Iguana*, *Cyclura*, and their allies, there is no trochlear surface above the condyles in front. Occupying its position there exists a large oblique groove (Fig. 1, *f*) or depression communicating with a short canal, which descends and expands in a funnel-like manner (Fig. 6, *f*) between the articulating surfaces of the condyles. The borders of the funnel-like expansion are ridged and grooved in the same manner as the exterior sides of the condyles. Posteriorly the latter are separated by a deep, wide notch. A deep popliteal concavity (Fig. 4, *g*) communicates below with a short, wide canal (Fig. 6, *g*) perforating the conjunction of the condyles posteriorly. A similar perforation exists in the recent *Cyclura.*

The posterior projection of the outer condyle is broken off in the specimen; that of the inner condyle exhibits a large rugged surface (Fig. 4, *d*) for the gastrocnemial attachment. The external condyle projects rather more inferiorly than the internal, but appears not to have been so extensive in its antero-posterior diameter.

The interior of the bone exhibits a capacious medullary cavity.

The measurements of the bone are as follows:—

	Inches.	Lines.
Length of the femur from top of trochanter to bottom of external condyle	41	6
Length from top of head to bottom of internal condyle . . .	39	
Breadth of upper extremity	9	3
Breadth of lower extremity	8	5
Transverse diameter at middle of shaft	5	2
Antero-posterior diameter at middle of shaft	4	6
Circumference below middle trochanteroid process	15	
Circumference above middle trochanteroid process	17	
Antero-posterior diameter of head	5	8
Antero-posterior diameter of trochanter	6	9
Antero-posterior diameter of inner condyle	10	

In comparing the femur of *Hadrosaurus* with that of the living *Cyclura* and *Iguana*, to which it bears a nearer resemblance than to that of the Crocodiles, it would appear as if the condition of most of the anatomical characters were either reversed or their meaning had been mistaken. Thus in *Hadrosaurus* we have described the head of the femur as being internal and the trochanter external. In *Cyclura* and *Iguana* the head of the bone is external and the trochanter postero-internal. In *Hadrosaurus* the head is slightly below the level of the trochanter; in *Cyclura* it is considerably higher. In *Hadrosaurus* the shape of the trochanter is nearly like that of the head in *Cyclura*, and is nearly as large as the head of the same bone, but in *Cyclura* it is much smaller. In the former the femur is longest from the trochanter to the external condyle; in the latter from the head to the external condyle. Lastly, in *Hadrosaurus* the internal condyle is the larger; in *Cyclura* the external is the larger.

The tibia of *Hadrosaurus*, represented in Figs. 1–6, Plate XVI, is of the left side. It approaches in form and details of structure that of the *Iguanodon*, as represented in Prof. Owen's Fig. 2, Plate XX, of the British Fossil Reptiles, Dinosauria. It is, however, proportionately more slender towards the middle of the shaft, and it appears twisted in such a manner that the broad extremities cross each other in the direction of their greatest diameter, whereas in *Iguanodon* the broad extremities are nearly on the same plane.

The tibia is about three feet in length, and is cylindroid at the middle of the shaft, which rapidly expands into broad, clavate extremities.

The fore part of the shaft, Fig. 1, is nearly straight vertically, is smooth, and widest at its upper part. For the greater part of its extent it is transversely convex, but towards its inferior extremity forms a sloping plane directed obliquely inward, and jutting forward at its termination.

The inner part of the shaft, Fig. 2, at the upper two-thirds is comparatively narrow and cylindroid. Below, it expands into a broad triangular plane directed somewhat backward, and rendered slightly concave transversely by the prominence of the anterior border, which ends in an angular, roughened process.

The outer part of the shaft, Fig. 3, is cylindrical, with a broad, wing-like expansion curving backward at its upper extremity, and terminating in a wide, triangular surface at its lower extremity.

The back part of the shaft, Fig. 4, is cylindroid at the middle, and rapidly expands above into a wide surface rendered transversely concave by the backward projection of the inner and outer portions of the head. At its lower third it rises into an acute ridge separating the inner and outer surfaces of the bone.

The head of the tibia, Figs. 1–5, in front and at the sides together, forms a semicircular outline. Its back part viewed from above exhibits three strong prominences. The inner two (Figs. 4, 5), nearly equal in size, form, and direction, constitute a pair of articular condyles separated by a deep notch. The outer prominence is formed by a wing-like expansion of the external part of the shaft, and is separated from the condyles by a wide, concave notch. The articular surface of the head is nearly a horizontal plane at its fore part, but is convex posteriorly as it extends upon the three backward prominences. It is rough and deeply marked with vascular grooves proceeding from the back part.

The tarsal articular surface, Fig. 6, has its long diameter in a reverse direction to that of the head of the bone. In outline it forms an irregular trapezium, with the short anterior side nearly straight and directed obliquely forward and inward, with the inner side gently sigmoid, the outer border deeply sigmoid, and the posterior shortest side straight and directed obliquely backward and forward. The surface is somewhat rough. In the direction of its long diameter, or antero-posteriorly, it is for the most part concave, but is convex at the back extremity. In the direction of its short diameter it is for the most part convex, but is depressed near the antero-internal angle.

The interior of the tibia possesses a large medullary cavity. The orifice of the medullary nutritious canal is directed downward and is situated at the postero-external part of the shaft just above its middle.

The measurements of the tibia are as follows:—

	Inches.	Lines.
Length of the tibia externally	36	9
Length in front	35	
Circumference at narrowest part of the shaft, being just below the middle	11	8
Breadth of the upper extremity	11	3
Diameter of middle of head antero-posteriorly	5	6
Breadth of tarsal extremity	10	
Diameter antero-internally	5	10
Diameter at middle of tarsal surface	2	10
Diameter postero-externally	3	4

As in the case of the femur, in comparing the tibia of *Hadrosaurus* with that of *Cyclura*, etc., we are struck with an apparent reversal of many of the anatomical characters. Thus in the former the bone is longest externally, in the latter internally; in *Hadrosaurus* the long diameters of the head and tarsal extremity are opposed; in *Cyclura* they are parallel.

The fibula, represented in Figs. 7, 8, Plate XVI, from the left side, has lost its upper fourth, and in its present condition measures twenty-eight inches in length. At the broken extremity it is trilateral; and it gradually expands in a flattened, clavate manner to the lower extremity. Externally, Fig. 7, the bone is transversely convex, and for the greater part of its extent internally is concave in the same direction. The tarsal articular surface, Fig. 8, is bent ellipsoidal in outline, and is convex and roughened. At the broken end the specimen measures one inch ten lines in diameter; the tarsal extremity is five inches and a quarter wide, and two inches and one-third in thickness.

The fibula of *Hadrosaurus* bears a near resemblance to that of *Iguanodon*, as represented in Prof. Owen's Figs. 3, 4, Plate XX, of the British Fossil Reptiles, Dinosauria.

The two bones, represented in Figs. 7–10, Plate XIV, from their proportions are supposed to belong to the metatarsus, and like the bones of the leg above described probably appertain to the left side.

The large specimen (Figs. 7, 8) has a cylindroid shaft, compressed from above downwards and moderately expanding towards the extremities. The tarsal extremity is trilateral, flattened below, convex above, and presents a triangular concave surface on its inner side. The tarsal articular surface is vertically crescentic in outline and moderately concave. The phalangial extremity is quadrate, deeply impressed at the sides for the attachment of lateral ligaments, convex above, and deeply notched below. Its articular surface is vertically convex, slightly depressed towards the middle inferiorly, and extends upon a pair of prominent condyles below. The measurements of the bone are as follows:—

	Inches.	Lines.
Extreme length	12	8
Length at its upper part	11	3
Breadth of shaft at middle	3	3
Depth of shaft at middle	1	9
Depth of tarsal extremity internally	4	6
Breadth of tarsal extremity at middle	3	4
Height of phalangial extremity from a level	4	2
Breadth of phalangial extremity above and below	4	2

The second specimen (Figs. 9, 10), suspected to belong to the inner toe, has the shaft cylindroid, but much compressed obliquely from within outwardly and above downward. The extremities are broadly expanded and oblique in their position. The tarsal extremity is more than twice the height of its breadth, and presents a long elliptical articular surface, moderately concave at its upper two-thirds and convex at its lower third. The phalangial extremity appears rhombohedral in outline with concave sides. Its articular surface is vertically convex and depressed towards the median line.

The measurements of this bone are as follows:—

	Inches.	Lines.
Extreme length	12	
Depth of shaft at middle	3	3
Thickness of shaft at middle	2	
Height of tarsal extremity	6	7
Width of tarsal extremity	3	
Height of phalangial extremity	5	6
Breadth of phalangial extremity above	3	9
Breadth of phalangial extremity below	4	1

A proximal phalanx of the hind foot, represented in Figs. 11, 12, Plate XIV, is the only bone of the toes preserved in the collection of *Hadrosaurus* remains. It bears a near resemblance in size and general form and proportions with the corresponding bone of the *Iguanodon*, as represented in Prof. Owen's Fig. 1, Plate XXI, of the British Fossil Reptiles, Dinosauria. It is oblong square and moderately expanded at the extremities. The proximal extremity, being the widest and deepest portion of the bone, presents a reniform articular surface, which is in the slightest degree concave. The distal extremity is deeply impressed at the sides for ligamentous attachments. The articular surface is likewise reniform in outline, vertically convex, and hardly depressed towards the median line. The measurements of this bone are as follows:—

	Inches.	Lines.
Extreme length	6	
Breadth at middle of shaft	3	9
Height at middle of shaft	2	4
Breadth of proximal extremity	5	4
Height of proximal extremity	3	2
Breadth of distal extremity	4	5
Height of distal extremity	2	2

Among the collection of *Hadrosaurus* remains are several bones whose position in the skeleton I am unable positively to determine. One of these, represented in Figs. 4, 5, Plate XVII, most nearly resembles that indicated by Prof. Owen[1] and Dr. Mantell[2] as the ilium of the *Iguanodon*.

Assuming the bone to be a left ilium, it consists of a broad, thick plate, prolonged into a long hook-like process, which curves backward and inward and is broken at the extremity. The opposite extremity of the bone is likewise broken. The inner border of the broad intermediate plate exhibits a long, ellipsoidal, irregular articular surface for junction with the sacrum. From the outer border of the plate there projects forward a massive trilateral tuberosity, roughened externally and at the summit, which probably corresponds with the process projecting from the fore part of the ilium in the *Iguana* and *Cyclura*. The length of the specimen in its present imperfect condition, measured in a straight line, is twenty-seven inches, and its greatest breadth is nine inches and a quarter. The sacral articular surface is a foot in length and about one-fourth that breadth.

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[1] British Fossil Reptiles, Dinosauria, Plates I and II.

[2] Petrifactions and their Teachings, page 306, lignograph 65.

Another bone, the character of which I have not satisfactorily determined, is represented in Fig. 13, Plate VIII. It bears a general resemblance to that indicated by Prof. Owen[1] and Dr. Mantell[2] as the clavicle of the *Iguanodon*, but appears to me rather to resemble the pubic bone of the *Iguana* and *Cyclura* than the clavicle of the same animals.

The specimen, broken at its upper extremity, consists of a long and nearly straight cylindroid shaft, expanding at its lower extremity into a broad, thin, and flattened triangular plate. The borders of the latter are concave, and its outer and inner angles below form thick tuberous processes. A smaller process likewise projects from the outer part of the shaft just before it expands. The length of the specimen in its present state is twenty-six inches, the circumference of its shaft five inches, and the breadth of its lower extremity ten inches and a half.

A specimen of what appears to be a sesamoid bone is tetrahedral, with two concave surfaces separated by a prominent acute ridge and defined by rugged borders, and with two opposed surfaces, of which one is convex and the other nearly flat. The three axes of the bone measure forty-three, forty-one, and twenty-four lines.

As regards the size, general form and construction, and the habits of *Hadrosaurus*, from the anatomical characters of the bones and teeth, we may safely infer that it bore a very near relationship with *Iguanodon.*

To *Hadrosaurus* we may estimate the number of cervical, dorsal, and lumbar vertebræ to have been twenty-four, as in the living *Iguana* and *Cyclura*, and as is supposed to have been the case in *Iguanodon.*

The sacrum was most probably composed as in the latter of six vertebræ.

In attempting to ascertain how many vertebræ would be required, in the intervals of those caudals in our possession, to complete the tail of *Hadrosaurus*, I have supposed the whole number of caudal vertebræ to have been about fifty.

By calculating the length of the vertebræ in different portions of the column, making proper allowance for the intervertebral fibro-cartilages, and giving about two feet and a half for the skull, I would estimate the entire length of *Hadrosaurus* to have been about twenty-five feet.

The enormous disproportion between the fore and hind parts of the skeleton of *Hadrosaurus* has led me to suspect that this great herbivorous Lizard sustained itself in a semi-erect position on the huge hinder extremities and tail while it browsed on plants growing upon the shores of the ocean in which it lived.

Undetermined Reptiles allied to Hadrosaurus.

In a number of instances bones, and fragments of others, have been presented to the Academy of Natural Sciences, approaching in size those of *Hadrosaurus*, though not positively referable to the same great Saurian. One of these specimens, represented in Figs. 1, 2, 3, Plate XVII, is a left humerus, from Monmouth County, New

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[1] British Fossil Reptiles, Dinosauria, Pl. I, II.

[2] Petrif., &c., page 306, Fig. 65.

Jersey, presented by Dr. J. H. Slack. It is nearly perfect, except that the lower end is mutilated. When first examined and compared with the corresponding bone of *Hadrosaurus* the differences which were observable, though not very remarkable, led me to suspect that it belonged to *Mosasaurus*. The fossils previously described as most probably representing the humerus of the latter would, of course, preclude such an idea.

The specimen is rather smaller than the humerus of *Hadrosaurus*, and bears a near resemblance to it, without, however, being identical in form. The two bones are represented in the Figs. 1–3, Plates XIV, XVII, an inspection of which serves to exhibit the differences better than they can be described. The main differences are briefly as follows: The specimen in question is shorter in relation with the breadth, especially of its upper part; the expansion of its upper outer part extends more inferiorly in relation with the length of the bone, and terminates more abruptly than in *Hadrosaurus*. The expansion just mentioned, viewed sideways in the latter (Fig. 3, Plate XIV), presents a single curved line from the summit of the external tuberosity; in the humerus under comparison the same line (Fig. 3, Plate XVII) is sigmoid, and ends below in a rough tubercle not existing in *Hadrosaurus*. The lower part of the expansion is also thicker and rougher than in the latter; and behind it is much more projecting, so that the surface of the shaft in this position is transversely concave, whereas in *Hadrosaurus* in the same direction it is convex. Independently of these differences, the Monmouth County humerus closely resembles that of *Hadrosaurus*. Its measurements, in comparison with those corresponding in the latter, are as follows:—

		Monmouth County Humerus.		Hadrosaurus Humerus.	
		Inches.	Lines.	Inches.	Lines.
Length,	estimated, under	21		22	6
Breadth at the tuberosities	about	6	9	6	10
Thickness at head		3	6	3	3
Breadth of shaft just above middle		5	6	5	4
Thickness in same position		2	5	2	4
Breadth of lower portion of shaft		2	10	3	2
Thickness of lower portion of shaft		2	9	2	9
Circumference of lower portion of shaft		9	2	9	6
Breadth at condyles,	estimated, under	5		5	
Diameter of head		2	4	2	6

Several fragments, apparently of both femora, of a huge animal, from the Marl, near Swedesboro, Gloucester County, New Jersey, were presented to the Academy by David Ogden. The more characteristic of these nearly corresponds in form with that portion of the femur of *Hadrosaurus* between the distal extremity and the process of the middle part of the shaft. If it really appertained to the Saurian just named, the breadth and thickness of the fragment, in relation with the length of the *Hadrosaurus* femur above described, would indicate the bone in its perfect condition to have been nearly five feet in length. The fragment in its present state is seventeen inches long. The lower end is composed of coarse, spongy substance, indicating its proximity to the articular extremity. The upper end is much less quadrate than the femur of *Hadrosaurus* would appear to be in a corresponding position, and is rather transversely reniform in outline. It exhibits a medullary cavity, occupied by a hard, ash-colored matrix, four inches and a half in transverse, and two inches and three-fourths in antero-posterior diameter, with walls of compact ossific substance from one to two inches and a quarter in thickness. The fragment at its narrowest point is seven inches wide, four inches and a half thick at the middle, five inches internally, and three inches and three-fourths externally.

A second of the fragments, above indicated, appears to be part of the inner side of the shaft of the femur just below the head, and measures nearly four inches in thickness. A third fragment appears to be from the inner side of the lower part of the shaft of the opposite thigh bone.

Several fragments of large bones, from the Green-sand of Monmouth County, New Jersey, were presented by Dr. J. H. Slack. One of the specimens appears to be from the middle of the shaft of the femur, but of this I am not certain, for what I take to be the inner half of the surface is so deeply eroded (apparently from the action of water to which it had been a long time exposed, while the other half was protected by the mud in which it lay imbedded at the bottom of the ocean) that its characteristic features are to a considerable extent lost. The fragment, about a foot and a half long, had the same quadrate form, and about the same size as the corresponding portion of the femur of *Hadrosaurus*. Its exposed medullary cavity, emptied of loose green sand with which it was filled, has a diameter of about three inches transversely, and two inches and a quarter antero-posteriorly, with the walls averaging an inch and a quarter thick.

Of the other fragments, presented by Dr. Slack, two belonged to the lower part of a fibula of the same form as that of *Hadrosaurus*, but considerably larger.

A specimen of a metatarsal bone, from Monmouth County, New Jersey, presented by Mr. Isaac M. Hopper, of Freehold, is represented in Figs. 7, 8, Plate XV. It is larger than either of those of *Hadrosaurus* above described, and also differs from them in form, though it exhibits sufficient likeness to one of them to lead to the opinion that it belonged to the same enormous Saurian. The proximal end has the same form as that of the metatarsal of *Hadrosaurus*, represented in Figs. 7, 8, Plate XIV. The distal extremity is less thick and has not such prominent condyles. The shaft is thicker, and its inner surface, instead of being narrowed from the extremities into a median prominence, forms a wide irregular plane. The measurements of the specimen are as follows:—

	Inches.	Lines.
Extreme length	13	6
Breadth of shaft at middle	3	
Depth of shaft at middle	2	3
Depth of tarsal extremity internally, about	5	6
Breadth of tarsal extremity at middle	3	3
Height of phalangeal extremity, from a level, about	3	8
Breadth of phalangeal extremity	4	

Another metatarsal bone, with its extremities mutilated, from Peale's Museum, formerly existing in Philadelphia, and probably obtained from the Green-sand of New Jersey, was presented by Dr. P. B. Goddard. It appears to have had the same form as the specimen just described, but was somewhat larger. The breadth of its shaft at the middle is three inches and three-quarters; its thickness two inches and a half.

Dr. Slack presented to the Academy four fossil bones, from the Green-sand of Monmouth County, New Jersey, which at first puzzled me as to their position in the skeleton. They bear a resemblance to the bodies of the sacral vertebræ of the *Iguanodon*, from which I suspect them to be the corresponding bones of a young *Hadrosaurus*. The specimens are all mutilated, and the best one is represented in Figs. 27, 28, Plate XIII, as a representative of the whole. Three of them are four inches and a half in length, the remaining one four inches. They are much constricted at the middle and rapidly expand towards the extremities, which terminate in slightly depressed or nearly plane, rough, cordiform articular surfaces. The lower part of the body forms a thick, transversely convex, carina-like ridge, deeply concave from before backward. The upper angles are bevelled off for conjunction with the sacral ribs or pleurapophyses, between which on each side is a wide notch, part of the foramen for the transmission of the sacral nerves. The sacral canal forms a deep groove, concave antero-posteriorly and transversely. Supposing that *Hadrosaurus* had six vertebræ to the sacrum, as in *Iguanodon*, the length of this bone in the young individual to which the specimens belonged would have measured about twenty-six inches in length.

Since writing the foregoing, Prof. Cook, of New Brunswick, New Jersey, has sent to me for examination a collection of fossils, from Monmouth County, New Jersey. Among them are several uncharacteristic fragments of bones of the extremities and portion of a vertebral body of some huge animal which I suspect to be *Hadrosaurus*. The specimens were obtained from the farm of the Rev. G. C. Schenk, of Marlboro, Monmouth County.

The collection also contains portion of the shaft of a femur, obtained by Dr. Conover Thompson, from Freehold, Monmouth County, probably belonging to a young *Hadrosaurus*. The specimen corresponds in form and construction with the middle part of the shaft of the femur of the Haddonfield *Hadrosaurus*, but is much smaller. It is four-sided, hollow interiorly, and exhibits the remains of the conspicuous process postero-internally. The shaft about the middle of the process measures three inches and three-quarters in diameter transversely, and a little over three inches antero-posteriorly.

A few remains have come under my observation, from the Green-sand formation of New Jersey, which indicate one, or perhaps two, comparatively small species of terrestrial or amphibious Sauria, apparently allied to *Hadrosaurus*.

One of the specimens, contained in the cabinet of the Academy, consists of an entire tibia, from Burlington County, and is represented in Fig. 3, Plate III. It resembles the tibia of *Hadrosaurus*, but besides being a very much smaller bone it is proportionately very much more slender; or, in other words, it is much longer in relation with the breadth of its extremities. The shaft is trihedral, and of nearly uniform diameter to within a few inches of the latter, which have nearly the same form and relative position in regard to each other as in *Hadrosaurus*. The interior of the bone is excavated with a capacious medullary cavity, which continues to within a short distance of the articular ends without being narrowed by an accumulation of spongy substance.

The measurements of the specimen are as follows:—

	Lines.	Inches.
Extreme length	15	6
Greater diameter at middle of shaft	1	4
Smaller diameter at middle of shaft	1	
Breadth of head	3	4
Thickness of head	2	1
Breadth of tarsal extremity	2	7
Thickness at inner anterior border of tarsal extremity	1	4

The other specimens referred to consist of several fragments of a tibia, portions of two metatarsals, and three phalanges, from a much larger individual, if not a different species, indicated by the tibia just described. The specimens are from Monmouth County, and were submitted to my inspection by O. R. Willis, of Freehold, through Prof. Cook.

The tibial fragments consist of the greater portion of the upper articular extremity (Fig. 6, Plate XVII), and the lower one (Fig. 7) preserved entire. Both have the same form as the corresponding portions of the tibia above described, but are much larger. Thus the thickness of the head is three inches; the breadth of the tarsal extremity is nearly four inches; and the thickness at the inner anterior border of the latter one inch and three-quarters. The medullary cavity is very capacious, being intermediate in this respect to the condition observed in ordinary mammals and birds. It reaches to within a short distance of the articular surfaces of the ends of the bone without being narrowed through the accumulation of cancellated substance.

One of the fragments of a metatarsal is represented in Fig. 8, Plate XVII. It is the distal end; has a quadrate shaft and a single articular head. The impressions for the attachment of lateral ligaments are remarkable for their depth. The interior of the fragment exhibits a medullary cavity corresponding in its capacity with that of the tibia.

The three phalanges (Figs. 9–11, Plate XVII) are all from the first series, and resemble the corresponding bones of Crocodiles; two are alike; the third is longer and narrower than the others. The proximal extremity, which is the broader, presents a single articular concavity. The distal extremity presents the common hour-glass-like or trochlear articular surface, and, as in the case of the metacarpal fragment just described, is depressed at the sides into deep pits, corresponding with the usual attachments of lateral ligaments.

The measurements of the shorter phalanges are as follows:—

	Inches.	Lines.
Length laterally	3	5
Breadth of proximal end	2	
Depth of proximal end	1	7
Breadth of distal end	1	6
Depth of distal end laterally	1	1

The measurements of the longer specimen are as follows:—

	Inches.	Lines.
Extreme length	3	10
Breadth of proximal end	1	6
Depth of proximal end at middle line	1	7
Depth of proximal end to a level	2	
Breadth of distal end	1	2
Depth of distal end laterally	1	3

ASTRODON.

Astrodon Johnstoni.

Astrodon, JOHNSTON, American Journal Dental Science, 1859.

Dr. Christopher Johnston has submitted to my inspection the greater part of a tooth, and a transverse section of another prepared by him for microscopic examination, of an extinct Reptile, for which he has proposed the name of *Astrodon.* The specimens of teeth were obtained by Mr. Tyson from an iron ore bed, considered as belonging to the Cretaceous epoch, near Bladensburg, Maryland.

The tooth of *Astrodon*, of which four views are given in Figs. 20–23, Plate XIII, bears considerable resemblance in form to the teeth referred to the *Hylæosaurus*, an associate of the *Iguanodon* and *Megalosaurus*, in the Wealden formation of Europe. The specimen comprises nearly the length of the crown, and is about an inch and a half long. The shaft of the crown is straight, compressed cylindroid, in transverse section ovate, the outer side strongly convex, the inner side much less so. The summit of the crown is compressed conical, curved inward, convex externally, depressed internally and sub-acute at the lateral borders, one of which is worn in the specimen so as to expose a narrow tract of dentine.

The transverse section of the tooth beneath the microscope, as represented in Fig. 10, Plate XX, exhibits an interior disk of dentine, with a multitude of minute tubuli radiating from the narrow elliptical section of the pulp cavity, surrounded by a thick layer of enamel.

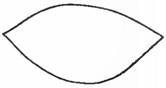
TOMODON.

Tomodon horrificus.

Among some teeth of Sharks, from Mullica Hill, Gloucester County, New Jersey, in the collection of Dr. William B. Atkinson, I observed a tooth different from any I had previously seen, from the Green-sand formations. The specimen represented in Figs. 7, 8, 9, Plate XX, Dr. Atkinson presented to the Academy of Natural Sciences. It appears to be the tooth of a gigantic carnivorous Reptile, a fitting contemporary of the *Hadrosaurus.*

The base of the specimen is broken away, and exhibits the remainder of the pulp cavity, which is small and of the form of the exterior of the tooth. The apex also is somewhat injured, though I have been unable to determine how much of the bluntness of the specimen is due to accident. It has the appearance as if it naturally terminated in a truncated manner; the enamel forming an abrupt ring surrounding a shallow depression of the dentine. The specimen to the extreme edge of the broken base is everywhere invested with thin, shining, and nearly smooth enamel, being only marked by feeble longitudinal striation and stronger transverse ridges of growth.

No. 35.



In shape the tooth is conical, strongly compressed from without inwardly, and has its broad surfaces defined before and behind by finely denticulated trenchant borders. In transverse section it forms a long ellipse with very acute poles, as seen in the outline, No. 35.

The length of the specimen in its present condition is two inches; the breadth just below the middle, where it is unbroken, is thirteen lines; and the thickness in the same position is seven lines.

Whether the tooth belongs to the same Reptile as some of the bones described in the preceding pages can only be conjectured, and under the circumstances I have indicated it under the name heading the present chapter. It may belong to *Discosaurus* or *Cimoliasaurus*, but the question can be determined only after further discovery.

PLIOGONODON.

Pliogonodon priscus.

Pliogonodon priscus, Leidy, Proceedings Academy Natural Sciences, Philadelphia, 1856, 255.
Pliogonodon nobilis, Leidy, Emmons, Report North Carolina Geological Survey, 1858, p. 223, figs. 43, 44.[1]

Under the above name I described the mutilated crowns of two teeth submitted to my inspection by Prof. Emmons, who obtained them from a Miocene deposit of Cape Fear, North Carolina. The specimens are, nevertheless, suspected originally to have belonged to the Green-sand formation. Their character I have not ascertained, and though I suspect them to have an affinity to *Mosasaurus*, they may be Crocodilian.

The specimens are elongated conical, in transverse section circular. One of them is straight, the other feebly curved. They are provided internally with acute ridges or carinæ, defining the inner and outer surfaces of the crown, which is subdivided into numerous narrow planes diversified with a few vertical interrupted plicæ more numerous on the inner surface. The base of the crown is hollowed; the dentine is fissured in concentric laminæ, and the enamel is minutely wrinkled. When perfect the crowns measured about two inches in length, and three-fourths of an inch in diameter at base.

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[1] The change of name I cannot account for except through inadvertence.

CHELONIA.

Remains of Turtles are not unfrequently discovered in the Green-sand formations of the United States, and many have been submitted to my inspection, especially from New Jersey. So little care, however, has been taken of these fossils, at the time of their discovery, that the fragments I have seen are scarcely more than sufficient to determine the order of animals to which they belong. Indeed, it has appeared to me that on the discovery of one or more of the plates which compose the shell or carapace and sternum of a Turtle the finder has amused himself in breaking the plates into as many bits as possible, though probably the destruction has rather been owing to the accidental blow of a pick or spade in digging the Marl in which the bones were imbedded. Most of the best preserved specimens I have had the opportunity of examining were obtained by Prof. George H. Cook, during his geological survey of New Jersey.

CHELONE.

Chelone sopita.

The remains of a supposed species of *Chelone*, from the Green-sand of Tinton Falls, Monmouth County, New Jersey, obtained by Prof. Cook, were first mentioned in a paragraph following a notice of remains of *Chelone grandæva*, a species of the Miocene period, in the Proceedings of the Academy of Natural Sciences of Philadelphia, Vol. VIII, page 303.

These remains consist of portions of four detached marginal plates of the carapace, which differ so much in breadth as to lead to the supposition that they may belong to two individuals of different age, if not to two species, though I suspect they really appertain to a single individual.

The plates are smooth, except that they present distinct vascular grooves, and each is crossed transversely about the middle by a furrow defining the separation of the marginal scutes. Their inner border is thick and longitudinally grooved, and is provided with a deep conical pit for the reception of a rib process from the costal plates. From the inner border the plates gradually and uniformly thin out to the acute outer edge. The upper surface is straight longitudinally, but slightly concave transversely, and the under surface is in the same degree convex. The transverse section forms a narrow isosceles triangle slightly curved.

One of the plates has a length of about three inches and a half, a breadth of three inches and a quarter, and a thickness at the inner border of seven lines. The fragment of a second plate, more curved than the others, has a breadth of three inches and a quarter, and a thickness at the inner border of 11 lines. A third plate is four inches and a half long, two inches and a half wide, and three-quarters of an inch thick at the inner border. The fragment of a fourth plate, less curved than the others, is two inches wide, and one inch thick at the inner border.

The collection of the Academy of Natural Sciences contains a series of three marginal plates, with the half of a fourth, from the Green-sand of Mullica Hill, Gloucester County, New Jersey, presented by Mr. J. Colson and Dr. Wm. B. Atkinson, which I suspect to belong to a younger individual of the same species as the preceding.

The series, represented in Fig. 5, Plate XIX, without having the means to determine their proper position, I nevertheless suspect to belong to the posterior portion of the left side of the carapace.

The plates rapidly increase in breadth passing backward. The inner border of the series forms a continuous groove, with a deep costal pit in each plate. The upper surface of the anterior plates slants evenly outward, but becomes slightly concave in the posterior plates. The under surface corresponds with the upper. The outer border is thin and acute, and at the junction of the plates appears to have been somewhat crenate. The outer border of the third plate of the series as it approaches the succeeding plate is notched half the width of the plate (*e*). The posterior border of the last plate of the series articulated with the succeeding one only at its outer half (*f*); the inner half (*g*) of this border being obtusely rounded, and it extends close upon the costal pit of the inner border. The surfaces of the plates are smooth or marked only by vascular grooves, and each is crossed by a furrow (*i*) defining the boundary of the scutes.

The breadth of the first of the plates is one inch and a half; its thickness internally ten lines. The length of the next plate is two inches eight lines; its breadth at middle one inch seven lines; its thickness nine lines. The length of the succeeding plate is two inches seven lines; its breadth two inches and a quarter; its thickness seven lines. The length of the last plate is two inches seven lines; its breadth two inches two lines; and its thickness half an inch.

Chelone ornata.

Chelone ornata, Leidy, Proc. Acad. Nat. Sci., Phila., 1856, VIII, 303.

The museum of the Academy of Natural Sciences contains a specimen consisting of conjoined portions of two marginal plates of a Turtle, obtained by Mr. L. T. Germain, from the Green-sand of Burlington County, New Jersey. The specimen is represented in Fig. 10, Plate XVIII, and though very imperfect is, nevertheless, characteristic on account of its markings. The plates measure about an inch and a half in breadth, and in transverse section are wedge-formed. Their inner border is eight lines high, and is grooved; the outer border is acute. Both upper and under surfaces slope evenly to the edges, and both are coarsely but beautifully tuberculated. In the perfect condition of the plates the tubercles appear to have had some tendency to a radiated arrangement. The fossil is supposed to indicate a species of *Chelone*, though future discoveries may determine it to belong to another genus.

EMYS.

Emys firmus.

Prof. Cook submitted to my inspection a number of fragments of Turtle shells, from the Green-sand formation of Tinton Falls, Monmouth County, N. J., among which are several marginal plates of a carapace and fragments of sternal plates, apparently belonging to the same individual. The osseous plates are as remarkable for their thickness as those of *Emys crassus*, from the Eocene sand of Hordwell, England, described by Prof. Owen.[1]

The specimens, also supposed to indicate a species of *Emys*, consist of fragments of the third, fifth, sixth, and seventh right marginal plates, a portion of the sixth and the nearly entire seventh left marginal plates of the carapace, and portions of the right hyposternal and left hyosternal plates of the sternum.

The exterior surface of the marginal plates is obscurely marked, as if impressed by a piece of lace, but on some of the specimens the marking is obliterated. The corresponding surface of the sternal plates is evidently smooth. Outlines of scutes on the marginal plates are so obscurely indicated as not to be distinctly traceable. The fragment of the hyposternal plate is crossed by a furrow defining the boundary of the abdominal and femoral scutes, but the hyosternal plate presents only a short interrupted furrow, which may be supposed to define the limits of the humeral and abdominal scutes.

The best preserved of the marginal plates, represented in Fig. 2, Plate XIX, the sixth and seventh of the left side, have their outer surface moderately convex, and sloping at an angle of nearly 45°. Their under part is strongly excavated to form the upper boundary of the back opening of the shell. The basal margin of the sixth plate is obtuse, but it becomes more acute as it extends along the seventh plate. The two plates together measure along the curve of the basal margin five inches and three-quarters. The width of the sixth plate about its middle is two inches and a half; that of the seventh is two inches and three-quarters, and its depth is three inches and three-quarters.

As indicated in Fig. 3, Plate XIX, the left hyosternal (*b*) articulated by a truncated angle with the right hyposternal plate (*d*) across the line of the median suture of the sternum, which was quite irregular in its course. The strongly truncated posterior angle of the right hyposternal plate would indicate that it also articulated with the left xiphisternal plate across the median suture. The anterior sutural border of the left hyosternal plate is sufficiently well preserved to indicate that the entosternal plate measured two inches in transverse diameter.

The left hyosternal plate along the line of the median suture measures two inches and a half; its width in the same direction at the outer boundary of the entosternal suture is three inches; its thickness at the inner angle of the latter suture is over an inch; its thickness at the angle of articulation with the hyposternal plate is five-eighths of an inch; and where thinnest, postero-externally, the fragment is half an inch.

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[1] British Fossil Reptiles, p. 76, pl. 38.

The right hyposternal plate, along the median suture, is two inches and a half; where widest, it measures in the same direction three inches and a quarter; where thickest, just back of the middle of the median suture, it is three-fourths of an inch; and where thinnest, externally, it is half an inch.

Emys beatus.

The museum of the Academy of Natural Sciences of Philadelphia contains several plates and fragments of others of a carapace of a Turtle, from the Green sand of Mullica Hill, Gloucester County, New Jersey, presented by William M. Gabb. The specimens, represented in Figs. 1–3, Plate XVIII, consist of part of the first vertebral plate, the entire third and fourth vertebral plates, portions of the first left and second and third right costal plates, and the greater part of the first left marginal plate.

The fragment of the first vertebral plate (*a*) is the anterior half, and is crossed near the broken edge by a groove, indicating the conjunction of the first and second vertebral scutes. The lateral borders are sub-angularly convex; the anterior border is irregularly angular. The broken edge is three lines and a half thick, from which position the plate thins away to the anterior border, where it measures one line and a half thick. The breadth of the plate about its middle is fifteen lines, the estimated length about thirty-four lines. The posterior portion of the plate, which is lost, judging from the corresponding margins of the first and second costal plates, appears to have been prolonged at its angles so as to join the antero-internal angles of the second costal plates.

The space occupied by the second vertebral plate is estimated to have been about twenty lines long and fourteen lines broad at its widest part. The lateral borders of the plate were subangularly convex; the posterior border convex.

The third and fourth vertebral plates (*b*, *c*), preserved entire, are elongated hexagonal, or wide coffin-shaped. The anterior border is concave, the posterior is convex. Of the lateral borders, which are straight, in the third plate the anterior is scarcely one-third the length of the posterior, and in the fourth plate the anterior is little greater than one-third the length of the posterior. The third plate is crossed just back of the middle by a groove, indicating the conjunction of the second and third vertebral scutes. Its length is two inches, its breadth at the widest part in front is seventeen lines, and its thickness five lines and a half. The length of the fourth plate is twenty-two lines, its breadth at the fore part sixteen lines, and its thickness is the same as the former.

The fragment of the first left costal plate (*d*) is the vertebral portion, and is grooved by the first and second vertebral scutes. It is thickest at the postero-internal angle, where it measures four lines and a half and thins away to three lines, two inches from the vertebral border. It appears not to have articulated with the second vertebral plate, from which it was separated by the prolonged basal angle of the preceding vertebral plate. Internally it presents a robust costal process for articulation with the first vertebra of the carapace.

The fragments of the second and third right costal plates are also vertebral portions, and both are devoid of internal costal processes for articulating with the vertebræ, as in some of the land Turtles. The second plate (*e*) is marked by grooves of the second vertebral and the first and second costal scutes. Its anterior angle articulated with the first vertebral plate, its posterior angle with the third, and the intervening border with the second. The narrowest portion of the fragment, within the space covered by the second vertebral scute, measures twenty-two lines, and the plate widens outwardly, to the broken margin where it is twenty-four lines. The thickness of the plate at the vertebral margin is four lines and a half anteriorly and five and a half posteriorly, and it thins outwardly to the broken margin where it measures three lines and a half. Fig. 2 represents an inner view of the fragment exhibiting the merest rudiment of a costal process at *f*.

The fragment of the third costal plate (*g*) comprises two inches and a half of its vertebral portion, which articulated with the third and fourth vertebral plates. It is marked by grooves of the second and third vertebral scutes, opposite which it measures twenty-three lines wide, and is reduced towards the broken outer margin to twenty-one lines. The thickness of the plate at the vertebral border is six lines, from which it thins off to the broken border to three lines and a half.

The first left marginal plate, Fig. 3, is marked by a crucial groove of the first and second marginal scutes, the first vertebral scute and the first costal scute. The marginal scutes did not extend to the middle of the length of the plate, the outer edge of which is acute and everted, and almost twice the breadth of the costal border. From the latter the plate increases in thickness to its middle, where it measures nearly seven lines, and then thins outwardly to the acute free margin.

The upper surfaces of all the plates present a closely, though somewhat obscurely pitted appearance, recalling to mind the rain-drop marking on muddy or sandy strata. This appearance, so different from the reticular furrowing on the lines of the Turtle previously described, precludes the idea of its belonging to the same. The slight variation in breadth and moderate curvature of the costal plates as they extend outwardly, indicate a depressed or low form of carapace as in the Terrapins. The absence of costal processes for articulating with the vertebræ, in the specimens of second and third costal plates, presents a relationship of structure with some of the land Turtles. Together the fossil fragments present characters sufficient to indicate a peculiar species.

Emys pravus.

Emys pravus, Leidy, Proc. Acad. Nat. Sci. Phila. 1856, 303.

Among the Turtle remains, obtained by Prof. Cook from the Green-sand of Tinton Falls, Monmouth County, New Jersey, are the greater portions of a hyosternal and hyposternal plates, and a small fragment of the conjoined xiphisternals. These are represented in Fig. 1, Plate XIX, and indicate a species differing from any of the preceding, and supposed to belong to the genus *Emys*.

The under surface of the sternum was generally flat, and appears to have been smooth, or without characteristic markings, though the eroded condition of the specimens renders this point uncertain. The marks of scutes, if they existed, are obliterated, or are so obscure as not to be traceable with any positiveness. The median suture is irregular in its course, as were also those sutures which crossed the sternum transversely.

Though the hyosternal (*b*) and hyposternal plates (*c*) are of far greater extent than in *Emys firmus*, they are absolutely very much thinner. The posterior angle of the right hyosternal articulates across the median sternal suture with the contiguous angle of the left hyposternal plate, which is provided with a tooth-like process received into a corresponding pit of the former plate.

The entosternal and episternal plates, judging from the forepart of the hyosternal, appear to have had the arrangement seen in our common Terrapins. The breadth of the entosternal space (*a*) between the hyosternal plates has been about two inches and a half; its depth between the same plates about one inch and a half. The estimated breadth of the sternum at the articulation of the epi- and hyosternals has been four inches and a half.

The length of the hyosternal plate along the median suture is four inches; its greatest length externally is five inches and three-quarters; the width of its episternal suture is one inch and a half; and its thickness is nearly uniformly about five lines.

The length of the hyposternal plate along the median suture is five inches; its greatest length, a short distance outwardly, five inches and three-quarters; and its thickness ranges from five to seven lines.

The xiphisternals (*e*, *f*) appear together to have been rounded off posteriorly and scarcely emarginate.

PLATEMYS.

Platemys sulcatus.

Platemys sulcatus, Leidy, Proc. Acad. Nat. Sci., Phila., 1856, VIII, 303.

Three consecutive marginal plates of the left side of a carapace, found in association with remains of other Turtles in the Green-sand of Tinton Falls, Monmouth County, New Jersey, and submitted to my inspection by Prof. George Cook, have been referred to the genus *Platemys*, from no other character, however, than their form. The plates articulated, as represented in Fig. 4, Plate XIX, are the fifth to the seventh, inclusive. Their outer side inclines at an angle of nearly 45°, but slopes in a gently curving manner more outwardly towards the thin acute basal margin, which is wider posteriorly than anteriorly. The surface is feebly marked with reticular furrows, and is grooved at the position of the borders of the marginal and costal scutes. The grooves defining the costal and marginal scutes cross the plates transversely just above their middle. The grooves defining the marginal scutes laterally descend along the middle of the plates. The three bones together, along the curve of their acute basal margin, measure eight inches. The under side of the plates is broad and flat.

With the marginal plates there was found a large fragment, apparently the greater portion of a xiphisternal plate of the same individual. The under surface exhibits the same kind of reticular furrows, as the marginal plates, but it is especially interesting from the fact that it presents on its upper surface an oblong elliptical suture for the pelvis. Such an articulation would, perhaps, indicate a nearer affinity of this extinct Turtle to the existing *Sternotherus*, than to *Platemys*, with which I have associated it.

I have also seen small fragments of two other xiphisternals, with the pelvic sutures, together with a fragment of a costal plate, apparently of a much younger individual, of the same species as the foregoing, obtained by Dr. Wm. B. Atkinson, from the Green-sand of Mullica Hill, Gloucester County, New Jersey.

BOTHREMYS.

Bothremys Cookii.

In June, 1862, Prof. Cook sent to me, for examination, the skull of a Turtle, from the Green-sand near Barnsboro, Gloucester County, New Jersey, which, independent of its special or generic peculiarities, is of interest from the circumstance that it is the first Chelonian skull brought to my notice from the Green-sand formations of the United States.

The specimen, represented in Figs. 4–8, Plate XVIII, consists of the greater portion of a skull together with the lower jaw. Of the former the occipital region, the auditory passages, the zygomatic arches, and some other minor parts are lost; of the latter the condyloid portions are destroyed.

Of all recent Turtles with which I am acquainted the fossil skull, in general physiognomy and structure, resembles most that of the great Turtle of the Amazon, *Podocnemys expansa.* From this, and all others, however, it differs in several striking peculiarities.

The fossil skull is remarkable for the great proportionate breadth of the face, due to the accommodation of a large conical pit formed by each maxillary bone, as seen in Fig. 7, *a.*

The top of the skull (Figs. 4, 6) is nearly flat, inclining forward in a slight degree, and becoming slightly more convex approaching the orbits and the interval between them. The face in the latter position is broad, slightly convex, and slopes regularly to the anterior nasal orifice. Below and behind the orbits the face is of great proportionate depth, and slopes obliquely downward and outward with a moderate degree of convexity. Transversely the lower boundary of the face forms a semicircle, broken only by a moderate pointed protrusion of the premaxillaries.

The orbits are comparatively small and circular, and look obliquely upward, forward, and outward.

The anterior nasal orifice is of great proportionate breadth, its transverse diameter being twice as great as the vertical. It is in the form of a double annulus or a prostrate figure of 8.

The temporal fossæ are large, but whether they have been covered by a bony vault, as in the great Turtle of the Amazon and the marine Turtles, cannot be ascertained in consequence of the imperfection of the fossil.

The upper jaw is defined below, in the usual manner in Turtles, by an acute ridge for accommodating the corneous dental armature of the jaw.

The most remarkable character of the skull is seen in the inferior view (Fig. 7). This consists of a deep conical pit (*a*) occupying each maxillary bone. The bottom of the pit extends as high as the position of the upper third of the orbit externally, and is imperforate. The pit expands regularly downward upon nearly the whole palatine surface of the maxillary bone, including a portion of the premaxillary and palate bones. The lower boundary, or mouth of the pit as it may be considered to be, forms an isosceles triangle, the apex of which, slightly prolonged, extends upon the premaxillary bone to the median palate suture, and the base is formed by the posterior, acute, crescentic border of the maxillary bone bounding the temporal fossa. The outer side of the triangle is constituted by the dentary margin of the jaw; and the inner side is formed by a ridge proceeding from the middle of the premaxillary bone obliquely outward and backward, just external to the posterior nares, and extending upon the palate bone. No intervening ridges occupy the triangle formed by the mouth of the pit.

The function of the latter it is difficult to comprehend. It does not appear like an alveolus for a tooth; but probably it may have accommodated a corneous tooth-like process springing from a corresponding hollow of the lower jaw.

The posterior nares are situated about ten lines behind the front of the jaw. They are circular, are separated by a strong osseous vomer, and are directed backward in the usual manner.

The base of the skull between the temporal fossæ presents a broad surface, which was apparently furnished at the sides with conspicuous pterygoid processes, as in the great Turtle of the Amazon.

A pair of small anterior palatine foramina occupied the suture between the premaxillaries, and apparently the vomer and palate bones.

A rather larger pair of posterior palatine foramina occupy the sutures between the palate and ali-sphenoid bones.

The orbits are separated from the temporal fossæ, as in the great Turtle of the Amazon, by a postero-external wall, which, so far as I can ascertain, appears to be composed of contributions from the post-frontal, parietal, malar, maxillary, and ali-sphenoid bones. As in the Turtle just mentioned, the orbit likewise communicates with the temporal fossa by a large aperture bounded externally by the scroll-like external pterygoid process. At the back part of the inner wall of the aperture the large foramen is situated, for the transmission of the trifacial nerve.

The sutures in the fossil are, in many cases, very indistinct, and in other cases the specimen has been fractured in their course, so that it is difficult to follow them or to determine the outlines of the individual bones.

The upper surface of the parietals are flat, and exhibit no markings of investing scutes, which is also the case with the other bones of the cranium.

The frontals are small, and their upper surface is flat. They are defined by an irregularly transverse suture from the parietals, by another directed forward to the middle of the top of the orbits from the post-frontals, and by an oblique one from the pre-frontals.

The pre-frontals, as in most Turtles, are not distinct from the nasals. They are larger than the frontals, and are defined from the maxillaries by an oblique suture proceeding from the nasal orifice to the inner and lower part of the orbit.

The post-frontals are broken away at their back part; their fore part forms the supero-external fifth of the orbits.

The back part of the malars is likewise broken; their fore part forms a narrow plate introduced between the post-frontal and posterior portion of the maxillary bone, as in *Podocnemys.*

From the broken boundary of the parietals, post-frontals, malars, and maxillaries in the fossil, I suspect a bony vault to have enclosed the temporal fossa, as in *Podocnemys* and the marine Turtles.

The mandible or lower jaw (Figs. 5, 8), as in the case of the upper maxillary bones, is remarkable for the deep pit (*b*) which occupies it on each side. The bottom of the pit corresponds with the posterior extremity of the dentary bone, and it expands, trumpet-like, obliquely forward and inward upon the upper surface of the mandible. The boundaries of the mouth of the pit correspond with the anterior and posterior dental ridges extending from the symphysis and meeting at the coronoid process.

The anterior dental ridge is directed forward and not upward in the usual manner. It is nearly on a level with the base of the jaw, which is almost flat.

The coronoid process is as robust and prominent as in the soft-shelled Turtles or *Trionyces.* Just back of its base is situated, as usual, the foramen for the inferior maxillary nerve, which likewise, as in other Turtles, communicates with a groove on the inner side of the ramus of the jaw.

The connections of the dentary with the other bones of the jaw are too obscure in the fossil to be traced with success.

Measurements obtained from the fossil skull are as follows:—

	Lines.
Height of skull from a level surface	16
Breadth of face at back part of maxillæ	32
Length of face from fronto-parietal suture to anterior nasal orifice	16
Diameter of orbits, transverse and vertical	7
Transverse diameter of anterior nasal orifice	10
Vertical diameter of anterior nasal orifice, each side	5
Depth of face below orbits	9½
Breadth of face between orbits	8
Length and breadth of each frontal bone	6
Length of fronto-nasals	9
Breadth of fronto-nasals at lower margin of orbits	7
Distance of posterior nares from margin of the premaxillaries	10½
Breadth together of the posterior nares	6½
Breadth of base of skull between the external pterygoid processes	19
Breadth of lower jaw at coronoid processes	23
Distance from coronoid process to pointed extremity of symphysis	21
Breadth of jaw at symphysis	9
Height of jaw at back of symphysis	6
Height of jaw at coronoid processes	13

The question may arise whether the fossil skull belongs to any of the preceding Turtles, and if so, to which. As it is impossible, under present circumstances, to give a satisfactory answer, I have considered the specimen as characteristic of a new genus, for which the name of *Bothremys* is proposed in allusion to the remarkable pits of the jaws. The species is dedicated to Prof. George H. Cook, of Rutger's College, New Brunswick, New Jersey, by whom the specimen was obtained, and through whose explorations our knowledge of the vertebrate fauna of the Green-sand formations of New Jersey has been greatly enriched.

TRIONYX.

Trionyx priscus.

Trionyx priscus, Leidy, Proceedings Academy Natural Sciences, Philadelphia, 1851, V, 329.

A species of soft-shelled Turtle of the genus *Trionyx* appears to have existed during the deposit of the Green-sand formations of the United States, as indicated by the discovery of several small fossil fragments. These remains, if correctly referred to their true geological and zoological position, are the oldest of the genus, for no authentic species have previously been found in older formations than the Eocene Tertiary strata. But all existing *Trionyces* inhabit fresh water, and the extinct species heretofore described have been obtained from fresh-water deposits. The discovery, however, of remains of *Trionyx* in a marine formation like the American Green-sand does not prove that the genus inhabited the seas of the Cretaceous period. The species most probably, as at the present time, lived in rivers, down which the remains were carried to be deposited in the Green-sand mud of the ocean.

The museum of the Academy of Natural Sciences contains a small portion of a costal plate of a *Trionyx*, from the Green-sand of Burlington County, New Jersey. The fragment, together with its costal ridge, is nearly half an inch in thickness; the plate away from the ridge is about three lines and a half in thickness.

A more characteristic specimen is represented in Fig. 9, Plate XVIII. It consists of the outer portion of a costal plate, apparently the sixth of the left side, and measures two inches and a half long. It was found in the marl on the farm of G. C. Shenck, Monmouth County, New Jersey, and was sent to me for examination by Prof. Cook. At the broken border it is one inch and a half wide; at the outer border two inches. The costal ridge ends in a robust and comparatively short free process. The thickness of the plate, together with the costal ridge, internally is four lines, externally six lines; the thickness of the plate before and behind the ridge about three lines and a half. The free surface of the plate is covered with a network of ridges, of which those proceeding antero-posteriorly are very coarse, while the transverse connecting ridges are much finer. The meshes of the network are hemispherical pittings.

Accompanying the specimens just described were two others, consisting of the acetabular portion of the pelvis and the upper extremity of the femur of the right side. The fragment of the femur, with the head mutilated, closely resembles in form the corresponding portion of the same bone in recent species of *Trionyx*. The breadth at the trochanters is twenty lines; the diameter of the shaft just below the latter from side to side was about six lines and a half; and from without inward it measures five lines.

I have also had the opportunity of inspecting a fragment of a costal plate of a *Trionyx*, about the size of that to which the specimens just described belonged, from the Cretaceous formation near Columbus, Mississippi, whence it was obtained by Dr. Spillman. The surface, however, is not so deeply pitted as in the costal fragments above described, nor are the ridges separating the pits so coarse. It probably indicates a different species.

A SYNOPSIS,

IN WHICH AN ATTEMPT IS MADE TO DEFINE MORE CLOSELY THE GENERA AND SPECIES OF REPTILES WHOSE REMAINS ARE DESCRIBED IN THE PRECEDING PAGES.

SAURIA.

THORACOSAURUS. Leidy.

1. Thoracosaurus neocesariensis.

New Jersey Gavial. DE KAY: An. Lyc. Nat. Hist. N. Y. 1833, III, 156, Pl. III, Fig. 7–10.
Gavialis neocesariensis. DE KAY: Zool. New York, 1842, III, 28, Pl. 22, Fig. 59.
Crocodilus s. Gavialis clavirostris. MORTON: Pr. Ac. Nat. Sci. Phil. 1844, III, 82.
Crocodilus basifissus. OWEN: Jour. Geol. Soc. Lond. 1849, V, 381, Pl. X, Figs. 1, 2.
Sphenosaurus. AGASSIZ: Pr. Ac. Nat. Sc. Phil. 1849, IV, 169.
Thoracosaurus grandis. LEIDY: Pr. Ac. Nat. Sc. Phil. 1852, VI, 35.
Pages 5–12, Plate I, Figures 1–6; Plate II, Figures 1–3; Plate III, Figures 5–11

BOTTOSAURUS. Agassiz.

2. Bottosaurus Harlani.

Extinct species of Crocodile. HARLAN: Jour. Ac. Nat. Sci. Phil. 1824, IV, 15, Pl. I.
Crocodilus Harlani. MEYER: Palæologica, 1832, 108.
Crocodilus macrorhynchus. HARLAN: Med. and Phys. Res. 1835, 369.
Bottosaurus. AGASSIZ: Pr. Ac. Nat. Sci. Phil. 1849, IV, 169.
Crocodilus basitruncatus. OWEN: Jour. Geol. Soc. Lond. 1849, V, 380.
Pages 12–14, Pl. IV, Figs. 19–21; Pl. XVII, Figs. 11–14.

CROCODILUS.

3. Crocodilus tenebrosus.

Page 14: Two cervical, a dorsal, the sacral, and two caudal vertebræ, and portions of both humeri, from Big Timber Creek, Gloucester Co., N. J. Pl. III, Figs. 12–15.

4. Crocodilus obscurus.

Page 15: Four vertebræ, the shaft of a femur, and four broken dermal bones, from Barnsboro, Gloucester Co., N. J., Pl. II, Figs. 4, 5.

Page 16, Two posterior dorsal or lumbar vertebræ, from Arneytown, Burlington Co., N. J.

Crocodiles of Uncertain Reference.

a. Page 16, Vertebræ, from Jobstown, Burlington Co., N. J. Pl. II, Fig. 6.
b. Pages 16, 17, A cervical vertebra, from St. George's, New Castle Co., Del. Pl. II, Fig. 7.
c. Page 17, Fragment of a left dental bone, from Monmouth Co., N J. Pl. IV, Figs. 22, 23.
d. Page 17, Fragment of a small *Gavial* skull, from Burlington County, N. J. Pl. II, Fig. 8.
e. Page 17, Four teeth, from Blackwoodtown, Camden Co., N. J. Pl. I, Figs. 7, 8, 9.
f. Page 17, Two teeth, from North Carolina. Pl. III, Figs. 22, 23.
g. Page 18, A dermal plate, fragment of a jaw and a tooth, from Burlington Co., N. J.

POLYPTYCHODON. Owen.

5. Polyptychodon ? rugosus.

Polyptychodon rugosus. EMMONS: North Carol. Geol. Surv. 1858, 219, Fig. 38.

Page 18, A tooth, from Elizabethtown, Bladen Co., N. C.

HYPOSAURUS. Owen.

6. Hyposaurus Rogersii.

Hyposaurus Rogersii. OWEN: Jour. Geol. Soc. Lond. 1849, V, 380, Pl. XI, Figs. 7–10.

Holcodus acutidens. In part, of GIBBES: Mem. on Mosasaurus, &c., Smiths. Contrib. 1850, II, 9, Pl. III, Fig. 13.

Pages 18–21, Pl. III, Figs. 4, 16–21; Pl. IV, Figs. 1–12.

DISCOSAURUS. Leidy.

7. Discosaurus vetustus.

Discosaurus vetustus. LEIDY: Pr. Ac. Nat. Sc. Phil. 1851, 326.

Pages 22–25, Pl. IV, Figs. 13–18; Pl. V, Figs. 1–12.

CIMOLIASAURUS. Leidy.

8. Cimoliasaurus magnus.

Cimoliasaurus magnus. LEIDY: Pr. Ac. Nat. Sc. Phil. 1851, 325; 1854, 72, Pl. II, Figs. 4–6.

Pages 25–29, Pl. V, 13–19; Pl. VI, Figs. 1–18

PIRATOSAURUS. Leidy.

9. Piratosaurus plicatus.

Pages 29, 30, Pl. XIX, Fig. 8.

MOSASAURUS. Conybeare.

10. Mosasaurus Mitchelli.

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Page 72, Teeth, No. 34. Pl. X, Figs. 18, 19.

HOLCODUS. Gibbes.

12. ? Holcodus acutidens.

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MACROSAURUS. Owen.

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Macrosaurus lævis. Owen: Jour. Geol. Soc. Lond. 1849, V, 380, Pl.

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POLYGONODON. Leidy.

15. Polygonodon vetus.

Polygonodon vetus. Leidy: Proc. Ac. Nat. Sc. Phil. 1856, VIII, 221.

Polygonodon rectus. Emmons: Rep. N. Car. Geol. Surv. 1858, 218, Fig. 37, A; Manual of Geology, 1860, 208, Fig. 3.

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Page 76, A tooth, from Burlington Co., N. J. Pl. IX, Figs. 12, 13.

HADROSAURUS. Leidy.

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Hadrosaurus Foulkii. Leidy: Proc. Ac. Nat. Sc. Phil. 1858, 218.

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18. Astrodon Johnstoni.
Astrodon. JOHNSTON: Amer. Jour. Dent. Science, 1859.
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Pliogonodon priscus. LEIDY: Pr. Acad. Nat. Sci. Phil. 1856, 255.
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CHELONE.

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Platemys sulcatus. Leidy: Proc. Ac. Nat. Sc. Phil. 1856, VIII, 303.
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Trionyx priscus. Leidy: Proc. Ac. Nat. Sc. Phil. 1851, V, 329.
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The specimens figured belong to the Museum of the Academy of Natural Sciences of Philadelphia, unless otherwise stated.

PLATE I.

Figs. 1–6. *Thoracosaurus neocesariensis.*

Fig. 1. Skull of *Thoracosaurus neocesariensis,* from the Cretaceous limestone of Vincenttown, Burlington County, New Jersey. Upper view, one-half the diameter of the original.

Fig. 2. Lateral view of the same specimen.

Fig. 3. Tooth of *Thoracosaurus neocesariensis,* from Burlington County, New Jersey. Lateral view, natural size.

Fig. 4. Tooth, from near Blackwoodtown, Camden County. External view, natural size.

Fig. 5. Tooth, found with that of Fig. 3. Lateral view, natural size.

Fig. 6. Tooth of the same species, from the limestone of Big Timber Creek, Gloucester County, New Jersey. Lateral view, natural size.

Figs. 7–9. Teeth of a *Gavial,* from Blackwoodtown, Camden County, New Jersey. Lateral views, natural size.

PLATE II.

Figs. 1–3. *Thoracosaurus neocesariensis.*

Fig. 1. Inferior view of one-half of the skull, one-third the diameter of nature. From the same specimen as Figs. 1, 2, of the preceding Plate.

Fig. 2. Fragment of the upper jaw, left side, from the Cretaceous limestone near Blackwoodtown, Camden County, New Jersey. One-half the diameter of the original. *a, b.* Maxillo-malar suture.

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Figs. 4–7. Vertebræ of Crocodiles, one-half the diameter of nature.

Figs. 4, 5. Two cervical vertebræ, probably the fourth and fifth, from Barnsboro, Gloucester County, New Jersey. Belonging to the collection of Rutger's College, New Brunswick, New Jersey.

Fig. 6. Cervical vertebra, probably the fifth, from Jobstown, Burlington County, New Jersey.

Fig. 7. Cervical vertebra, from St. George's, New Castle County, Delaware.

Fig. 8. Upper view of a fragment of a small *Gavial* skull, from the Green-sand of Burlington County, New Jersey. One-half the diameter of nature. *a,* Frontal; *b,* orbital margin; *c,* parietal; *d,* coronal suture.

Figs. 9–11. Posterior dorsal vertebræ of *Hadrosaurus Foulkii,* one-third the diameter of nature.

Figs. 9, 10. Lateral view, left side.

Fig. 11. Anterior view of the same specimen as Fig. 9. These figures were accidentally left out of their proper position among the Plates, and have been introduced in Plate II, which was drawn after all the others.

Figs. 12–14. An inferior tooth of *Trachodon mirabilis*, from the Bad Lands of the Judith River, Upper Missouri, of the natural size. The fang is lost.

Fig. 12. External view.

Fig. 13. Lateral view.

Fig. 14. Internal view.

These figures are introduced for comparison with those of the teeth of *Hadrosaurus Foulkii*, and were accidentally left out of their proper place.

Figs. 15, 16. A caudal vertebra of an undetermined Saurian, from a Cretaceous formation of Nebraska, presented to the Academy of Natural Sciences of Philadelphia by Dr. Hiram A. Prout. The figures are of the natural size. Viewed from the extremities the specimen presents a somewhat hexahedral outline. The vertical diameter of the body is greater than the transverse diameter, and is nearly twice as great as its length. The sides are moderately constricted. The anterior surface, as I suppose it to be, is concave, the posterior surface, in a corresponding degree, convex. From the under part of the body project two short, robust processes, with an excavated articular facet for junction with a chevron bone. The measurements of the specimen are as follows:—

	Lines.
Length	10
Breadth	15
Height	19
Depth of concavity in front	2
Width of spinal canal at the middle of the broken abutments of the arch	2½

PLATE III.

Figs. 1, 2. A dorsal vertebra of *Macrosaurus lævis*, from Monmouth County, New Jersey, one-half the diameter of the original.

Fig. 1. Lateral view; *a*, anterior; *p*, posterior.

Fig. 2. Anterior view.

Fig. 3. Tibia of an undetermined Reptile, from the Green-sand of Burlington County, New Jersey, one-half the diameter of the original.

Fig. 4. Fragment of a femur of *Hyposaurus Rogersii*, from near Blackwoodtown, Camden County, New Jersey, one-third the diameter of the original.

Figs. 5–11. Vertebræ of *Thoracosaurus neocesariensis*, one-half the diameter of the originals.

Figs. 5, 6. Cervical vertebra, from Burlington County, New Jersey.

Fig. 5. Inferior view.

Fig. 6. Lateral view; *a*, anterior; *p*, posterior.

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Fig. 9. The eighth and ninth dorsals, coossified by a large exostosis, right lateral view.

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Fig. 19. Internal view of a larger tooth.

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Fig. 2. Posterior cervical vertebra, from Tinton Falls, Monmouth County, New Jersey, belonging to the collection of Rutger's College. Lateral view. *a*, anterior; *p*, posterior.

Fig. 3. Fourth dorsal vertebra, belonging to the same individual and collection as the preceding specimen. Lateral view. *a*, anterior; *p*, posterior; *h*, hypapophysis broken off.

Figs. 4, 5. Dorsal vertebra, from the same individual as the specimen of Fig. 1

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Fig. 5. Lateral view, or left side. *a*, anterior; *p*, posterior.

Figs. 6, 7. Dorsal vertebra, from Burlington County, New Jersey.

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Fig. 7. View of right side.

Fig. 8. Caudal vertebra, from the same individual as specimens of Figs. 1, 4, 5. View of the left side.

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Fig. 9. Posterior view.

Fig. 10. View of left side.

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Figs. 13–18. *Discosaurus vetustus.* One-half the diameter of the originals. From the same skeleton as the specimens represented in Figs. 1, 2, 3, 7, 8, 9, Plate V.

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Fig. 23. Upper view.

PLATE V.

All the figures are reduced one-half the diameter of the original specimens.

Figs. 1–12. Vertebræ of *Discosaurus vetustus.*

Figs. 13–19. Vertebræ of *Cimoliasaurus magnus.*

Figs. 1–3. Cervical vertebra of *Discosaurus vetustus,* from Burlington County, New Jersey.

Fig. 1. Lateral view; *a,* anterior surface of body; *p,* posterior surface; *c,* costal pit.

Fig. 2. Posterior view.

Fig. 3. Inferior view; the upper part is the anterior.

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Fig. 4. Lateral view. *c,* costal pit.

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Fig. 6. End view of a second specimen.

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Fig. 11. Lateral view.

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Fig. 14. End view of the same specimen.

Fig. 15. Lateral view of the same.

Fig. 16. Lateral view of a more anterior dorsal vertebra.

Figs. 17–19. A lumbar vertebra found with the preceding dorsals.

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PLATE VI.

Vertebræ of *Cimoliasaurus magnus,* one-half the diameter of the original specimens. Those from Fig. 1 to 15, inclusive, were obtained together, from Freehold, Monmouth County, New Jersey, and apparently belonged to the same individual. From the collection of O. R. Willis.

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Fig. 16. Inferior view.

Fig. 17. Lateral view.

Fig. 18. End view.

PLATE VII.

All the figures are reduced one-half the diameter of the originals, excepting Fig. 16, which is of the natural size.

Figs. 1–18. Vertebræ of *Mosasaurus*.

Figs. 19, 20. Vertebra of *Macrosaurus*.

Fig. 1. Cervical vertebra of *Mosasaurus*, from Monmouth County, New Jersey. Posterior view. *a*, Articular processes; *t*, transverse process; *h*, hypapophysis; *p*, posterior convex surface of the body.

Fig. 2. Cervical vertebra, from Burlington County, New Jersey. Inferior view. *a*, Anterior concave surface of the body; *p*, posterior convex surface; *t*, transverse process; *h*, hypapophysis.

Fig. 3. Posterior view of the same specimen as the last. *t*, Transverse process; *h*, hypapophysis.

Figs. 4–7. Vertebræ, from Columbus, Mississippi, belonging to Dr. Spillman.

Fig. 4. Cervical vertebra. Inferior view. *a*, Anterior; *p*, posterior.

Fig. 5. Another cervical vertebra, from the same individual as the last. Lateral view. *a*, Anterior; *p*, posterior surface of the body; *h*, hypapophysis; *ar*, articular process; *s*, spinous process; *t*, transverse process.

Fig. 6. Posterior view of the same specimen as the last. *s*, Spinous process; *a*, articular process; *t*, transverse process; *h*, hypapophysis.

Fig. 7. Fragment of a dorsal vertebra, from the same individual as the last. Inferior view. *a*, Anterior; *p*, posterior; *t*, transverse process.

Fig. 8. Dorsal vertebra, from Monmouth County, belonging to Dr. C. Thompson. Posterior view.

Figs. 9–11. Lumbar vertebra, from Burlington County, New Jersey.

Fig. 9. Inferior view.

Fig. 10. Lateral view.

Fig. 11. Posterior view. *a*, Anterior; *p*, posterior; *t*, transverse processes.

Fig. 12. Another lumbar vertebra, from Burlington County. Lateral view.

Fig. 13. Lumbar vertebra, from Freehold, Monmouth County. Lateral view.

Fig. 14. Posterior view of the same specimen. *t*, Transverse process.

Fig. 15. Portion of a series of posterior caudal vertebræ imbedded in a mass of rock, from the Yellowstone River, Nebraska. Lateral view. *a*, Anterior; *p*, posterior; *s*, spinous processes; *c*, chevron bones.

Fig. 16. A posterior caudal vertebra, from the same individual as the last. Lateral view. Natural size. *a*, Anterior; *p*, posterior part of the body; *v*, vertebral arch; *c*, chevron bone.

Fig. 17. Body of a posterior caudal vertebra, from the Cheyenne River, Nebraska. Lateral view. *a*, Anterior; *p*, posterior; *v*, abutment of the vertebral arch; *c*, abutment of the chevron bone.

Fig. 18. Posterior view of the same specimen as the last.

Fig. 19. Supposed vertebra of *Macrosaurus*, from Freehold, Monmouth County. Inferior view. *a*, Anterior concave surface of body; *p*, posterior convex surface; *t*, transverse processes.

Fig. 20. Posterior view of the same specimen as the preceding.

PLATE VIII.

Figs. 1, 2. Humerus of *Mosasaurus*, one-half the diameter of nature, from near Columbus, Mississippi, belonging to the collection of Dr. Wm. Spillman.

Fig. 1. Posterior view.

Fig. 2. Anterior view. *a*, Head of the bone; *b*, greater tuberosity; *c*, lesser tuberosity; *d*, strong impression of muscular attachment. Length of the original specimen about ten inches.

Figs. 3, 4, 5. Proximal extremity of a huge bone, supposed to be of a humerus of the *Mosasaurus*, a little less than one-third the diameter of nature. The original measures eleven inches in length from the summit of the greater tuberosity to the broken end of the shaft. From the Green-sand of Burlington County, New Jersey.

Fig. 3. Posterior view.

Fig. 4. Anterior view.

Fig. 5. Outer or posterior border view. *a*, The head of the bone; *b*, greater tuberosity; *c*, lesser tuberosity; *d*, impression of muscular attachment.

Fig. 6. An isolated bone, probably a radius of a small species of *Mosasaurus*, or of a young animal, half the size of nature. Belonging to Prof. James Hall, and obtained by Messrs. Meek and Hayden, from a Cretaceous deposit of Nebraska. Length of the original specimen about two inches and three-quarters.

Fig. 7. Supposed radius of *Mosasaurus*, one-half the diameter of nature, belonging to the same skeleton and collection as the humerus above indicated, from Columbus, Mississippi. Length of the specimen two inches.

Fig. 8. Supposed carpal bone of *Mosasaurus*, the size of nature. From formation, No. 4, on the Big Cheyenne River; an isolated specimen, discovered by Dr. F. V. Hayden.

Fig. 9. Reptile bone, undetermined, one-half the size of nature. The specimen belongs to Prof. James Hall, and was found by Messrs. Meek and Hayden, five miles below Daurion's Hill Nebraska, among loose fragments at the base of a Cretaceous bluff.

Fig. 10. Reptile bone, undetermined, half the size of nature, found in company with that of Fig. 8. Length one inch and three-quarters.

Fig. 11. Basi-sphenoid bone of *Mosasaurus*, one-third the diameter of nature, from Holmdale, Monmouth County, New Jersey, belonging to the collection of Prof. George H. Cook. Length of original eight inches, breadth at the posterior diverging processes six inches. *a*, Anterior; *b*, posterior processes articulating with the basi-occipital bone.

Fig. 12. Dermal plate of a *Gavial*, from Burlington County, New Jersey, belonging to the collection of the Burlington Lyceum. One-half the natural size.

Fig. 13. Supposed pubic bone of *Hadrosaurus Foulkii*, one-fourth the diameter of the original specimen.

PLATE IX

All the figures are of the natural size.

Fig. 1–11. *Mosasaurus*.

Fig. 1. Inner view of an alveolar fragment, apparently from the upper jaw, from Burlington County, New Jersey. *a*, A nearly entire tooth, exhibiting on the inner side of the crown the subdivisional planes; *b*, exserted portion of the fang, which is coossified with its alveolus and excavated into a large cavity for a successor; *c*, bottom of the cavity, exposed by the loss of a thin plate of bone belonging to the alveolus; *d*, orifice of the cavity at the margin of the jaw postero-internally to the fang of the functional tooth; *e*, portion of the alveolus in front; *f*, exserted portion of the fang of a tooth, the crown of which is broken off; *g*, bottom of the fang exposed by the breaking away of a thin portion of the jaw-bone; the sides of the fang are firmly coossified with the alveolus; *h*, orifice of the cavity for a successional tooth; *i*, thin shell of bone remaining from the fang of a tooth, and closely coossified with the sides of the alveolus.

Fig. 2. Antero-internal view of an anterior tooth, from Monmouth County, New Jersey. *a*, External surface of crown; *b*, internal surface; *c*, fang.

Fig. 3. Antero-internal view of an anterior tooth, from Monmouth County, New Jersey, belonging to Rutgers College. *a*, External surface of crown; *b*, internal surface; *c*, fang.

Fig. 4. Inner view of an anterior tooth, from Monmouth County, New Jersey. *a*, Inner surface of the crown; *b*, impression of cavity for a successional tooth.

Fig. 5. Small fragment of a jaw, with a tooth and portion of another, inner view, from Monmouth County, New Jersey. *a*, Internal surface of the crown exhibiting the divisional planes; *b*, portion of crown of the adjoining tooth; *c*, exserted portion of fang; *d*, portion of fang within alveoli and coossified therewith; *e*, three large cavities for successional teeth; *f*, communication of the latter cavities with the pulp cavities of the teeth in use.

Fig. 6. Tooth, with small attached portions of the jaw, found with that of Fig. 5, and from the same individual. Internal view. *a*, Inner surface of crown; *b*, exserted portion of fang; *c*, portion of fang coossified with the interior of the alveolus; *d*, fragment of outer part of the jaw; *e*, large cavity, apparently for a pair of successional teeth; *f*, large pulp cavity.

Fig. 7. Tooth, internal view, from Monmouth County, New Jersey. *a*, The inner surface of the crown, which is devoid of divisional planes; *b*, fang without trace of coossific attachment.

Fig. 8. Inner view of the crown of a shed tooth, from Monmouth County, New Jersey, belonging to Dr. C. Thompson. It resembles the corresponding part of a Crocodile tooth more than the ordinary forms of the *Mosasaurus* teeth.

Figs. 9, 10. Two teeth, internal view, from Mount Holly, Burlington County, New Jersey. From the color and structural appearance the two teeth look as if they had been derived from the same individual. The crowns bear a close resemblance to the corresponding part of the teeth of the Crocodile. *a*, Impress upon the postero-internal surface of the fang of a cavity for a successional tooth. The specimen, represented by Fig. 9, is a shed crown, as proved by the excavated appearance of the base.

Fig. 11. Shed crown of a tooth, from St. George's, New Castle County, Delaware. Internal view. It strongly resembles a Crocodile tooth.

Figs. 12, 13. Tooth of *Polygonodon vetus*, from Burlington County, New Jersey, from the collection of Prof. Cook.

Fig. 12. Posterior view.

Fig. 13. External view.

PLATE X.

All the figures, representing teeth of *Mosasaurus*, are of the natural size.

Fig. 1. Tooth, from Freehold, Monmouth County, New Jersey, belonging to Dr. C. Thompson. Inner view. *a*, The crown exhibiting divisional planes of the inner surface well-marked; *b*, the osseous fang, longitudinally furrowed, and exhibiting no trace of former attachment with the sides of the socket in which it was inserted; *c*, impression of a cavity originally occupied by a successor to the tooth placed in advance; *d*, deeper cavity for a successional tooth.

Fig. 2. Tooth, from Monmouth County, belonging to Rutgers College. Outer view. The crown exhibiting one of the acute ridges which separate the outer surface *a*, from the inner surface *b*; both the latter present well-marked divisional planes; *c*, the fang, which was coossified with its alveolus, a fragment of the jaw being seen at *d*.

Fig. 3. The shed crown of a tooth, from near Woodbury, Gloucester County, New Jersey. Lateral view. *a*, Outer; *b*, inner surface, separated by a sub-denticulated ridge, and both presenting divisional planes.

Fig. 4. Tooth, from Monmouth County, New Jersey, from the same individual as those represented in Figs. 7–10, and Figs. 5, 6, Plate IX. Internal view. *a*, Inner surface of the crown, which has but one carina; *b*, exserted portion of fang; *c*, bottom of fang, which was coossified with its alveolus; *d*, large cavity for a successional tooth.

Fig. 5. Tooth, the fang broken off, from Monmouth County, New Jersey. Postero-lateral view. *a*, Inner, and *b*, outer surface of the crown, both of which are smooth.

Fig. 6. Mutilated shed crown of a tooth from Burlington County, New Jersey. Inner view. Besides exhibiting the divisional planes it is unusually striated.

Figs. 7–10. Teeth of *Mosasaurus*, from Monmouth County, New Jersey, from the same individual.

Fig. 7. Internal view. The summit of the crown worn off; the fang coossified with the alveolus. *a*, Exserted portion of fang; *b*, inserted portion, coossified with its alveolus; *c*, cavity for a successional tooth hollowed in the fang.

Fig. 8. Internal view of another tooth. The summit of the crown more worn than in the preceding. References the same as in last figure.

Fig. 9. Outer surface of the crown of the same tooth.

Fig. 10. Internal view of another tooth. The fang presents two excavations for successional teeth. *a*, Exserted portion of fang; *b*, inserted portion, coossified with its alveolus; *c*, *d*, cavities for successional teeth; *e*, the pulp cavity exposed.

Fig. 11. Internal view of the crown of a tooth, broken from the fang, from Monmouth County, New Jersey. Both sides of the crown are totally devoid of subdivisional planes.

Fig. 12. Shed crown of a tooth, from St. George's, New Castle County, Delaware. External view.

Fig. 13. Inner view of a specimen similar to the last, from Gloucester County, New Jersey.

Figs. 14, 15. Two teeth, from Freehold, Monmouth County, New Jersey, belonging to Dr. C. Thompson.

Fig. 14. Outer view of one specimen.

Fig. 15. Inner view of the second specimen. *a*, Exserted portion of fang; *b*, inserted portion; *c*, cavity for a successor.

Fig. 16. Tooth, from Mullica Hill, Gloucester County, New Jersey. Outer view. The fang has been broken off.

Fig. 17. Crown of a tooth, from a Cretaceous formation of Alabama. Lateral view. The specimen belongs to Dr. R. W. Gibbes, and is figured (*Mosasaurus* and the allied Genera. Smiths. Cont. Pl. III, Figs. 6–9) by him as characteristic of *Holcodus acutidens*. The outer (*a*) and inner surfaces (*b*), separated by acute ridges in front and behind, are subdivided into planes, which are somewhat depressed and striated.

Fig. 18. Crown of a tooth, from a Cretaceous deposit, marked No. 4, in the section of Dr. Hayden, at the mouth of White River, Nebraska. Lateral view. It resembles the tooth represented in the preceding figure, but is without the subdivisional planes. *a*, Section of the crown in outline; *b*, section at the base of the crown.

Fig. 19. Specimen, from the same locality as the preceding, retaining a portion of the crown and fang. *a*, Section at the broken surface of the crown; *b*, section at the base of the crown

PLATE XI.

All the figures, representing fragments of jaws and teeth of *Mosasaurus*, are of the natural size, excepting Fig. 13, which is one-half the diameter of the original.

Figs. 1–4. Fragments, from Holmdale, Monmouth County, New Jersey, belonging to Prof. Reiley, of Rutgers College.

Figs. 1, 2. Portions of the right pterygoid bone. *a*, *b*, *c*, Remains of the first, second, and third teeth; *d*, the fourth tooth; *e*, *f*, the seventh and eighth teeth.

Fig. 3. Posterior fragment of the right dental bone, containing an entire penultimate tooth. In the specimen the fang of the tooth is visible through the large foramen beneath, but has been inadvertently left out by the artist.

Fig. 4. Fragment of the left side of the lower jaw, inner view, containing the antepenultimate tooth entire. *a*, Cavity for a successional tooth; *b*, exserted portion of the fang of the tooth in advance, the crown having been broken off; *c*, its successor exposed by the destruction of the inner wall of the cavity containing it; *d*, minute successor included within the former, and accidentally

exposed by fracture and loss of portion of the tooth; *e*, vasculo-neural foramen in the outer parapet of the jaw.

Fig. 5 Fragment of a pterygoid bone with a penultimate tooth, inner view, from Monmouth County, New Jersey. The tooth resembles the corresponding one in the specimen represented in Fig. 1. *a*, Cavity for the successional tooth.

Fig. 6. Fragment of a lower jaw, inner view, from Monmouth County, New Jersey. *a*, Tooth, the fang of which is coossified with its alveolus; *b*, successional cavity; *c*, fang of the tooth in advance, the crown having been shed; *d*, fully developed crown of a successor included within its cavity; *e*, cavity for a successional tooth; *f*, portion of a vacant alveolus.

Fig. 7. Outer view of the successional tooth removed from the preceding specimen.

Fig. 8. Fragment of a lower jaw, inner view, from Monmouth County, New Jersey. The inner wall of the jaw was removed by accident, and exposes the fangs of the teeth, successional cavities, and dental canal. *a*, Remains of a fang coossified with its alveolus, and deeply excavated for the reception of a successional tooth; *b*, tooth in advance, the crown broken off, the fang entire and loose in its socket, from which it may be lifted out; *c*, cavity for a successional tooth; *d*, fang firmly coossified with its socket, and deeply excavated into a cavity containing a successor; *e*, fang of a tooth loose in its socket.

Fig. 9. Outer view of the successional tooth seen in place in the preceding specimen.

Fig. 10. Inner view of a tooth, with a small portion of the jaw, from Monmouth County, New Jersey, belonging to the collection of Mr. Willis. *a*, Exserted portion of the fang; *b*, inserted portion coossified with its socket; *c*, cavity for a successor.

Fig. 11. Inner view of a successional tooth, from Marlboro, Monmouth County, New Jersey, belonging to Rutgers College. It is totally devoid of subdivisional planes.

Fig. 12. Crown of a tooth, broken from its fang, outer view, from Monmouth County. It exhibits only the faintest trace of subdivisional planes.

Fig. 13. Anterior extremity of the right side of the lower jaw, external view, half the diameter of nature. From Freehold, Monmouth County, New Jersey. From Dr. Thompson's collection.

Fig. 14. Pterygoid bone, with teeth, inner view. Specimen obtained in Mississippi, and belonging to Dr. Spillman. *Holcodus?*

Fig. 15. Crown of a tooth of *Mosasaurus*, inner view, from Burlington County, New Jersey. An acute ridge exists alone along its concave border.

PLATE XII.

Vertebræ of *Hadrosaurus Foulkii*, one-third the diameter of the original specimens.

Figs. 1–3. Cervical vertebræ. Left lateral view. The side of the specimen of Fig. 1 is mutilated by a large excavation. That of Fig. 2 is less mutilated in the same manner. That of Fig. 3 is broken at the posterior inferior part.

Fig. 4. An anterior dorsal vertebra. Left lateral view.

Fig. 4, *a*. Posterior view of the same specimen.

Figs. 5–8. Dorsal vertebræ from the middle of the series.

Figs. 9, 10. Anterior caudal vertebræ.

Figs. 11–16. Middle caudal vertebræ.

Figs. 17–20. Posterior caudal vertebræ.

Fig. 20, *a*. End view of Fig. 17.

PLATE XIII.

Figs. 1–19. Teeth of *Hadrosaurus Foulkii*, of the natural size.

Figs. 1–4. A nearly perfect unworn inferior tooth.

Fig. 1. Inner view.

Fig. 2. Outer view.

Figs. 3, 4. Lateral views. *a*, Crown, on the inner surface invested with enamel; *b*, fang, grooved on the inner part for adaptation to the outer border of a successional tooth; *c*, surface, impressed apparently by contact with the side of the apical half of the crown of an infero-lateral successional tooth; *d*, portion of the denticulated enamel border of the crown magnified about six diameters.

Figs. 5–7. An inferior tooth with the apical half of the crown worn off.

Fig. 5. Outer view.

Fig. 6. Inner view.

Fig. 7. Lateral view. *a*, Triturating surface of the crown; *b*, cutting edge of the triturating surface.

Figs. 8, 9. An inferior tooth with the summit of the crown worn off.

Fig. 8. Outer view.

Fig. 9. Lateral view.

Figs. 10–13. A superior unworn tooth, with the greater portion of the fang lost.

Fig. 10. Outer view of the crown invested with enamel.

Fig. 11. Inner view.

Figs. 12, 13. Lateral views. *a*, Surface impressed by the apical half of the lateral successional teeth; *b*, surface impressed by the outside of the apex of the successional tooth above or in the same line; *c*, strong carina of the external enamelled surface of the crown.

Figs. 14–17. A superior tooth with the summit of the crown worn off. References as in the preceding tooth.

Figs. 18, 19. Ideal representation of the supposed arrangement of the teeth of *Hadrosaurus* in the relationship of the functional and successional teeth.

Fig. 18. External view of the relationship of the inferior teeth. *a*, Triturating surfaces of the teeth; *b*, teeth with the apical half of the crown worn away; *c*, tooth with its apex *d*, worn off; *e*, tooth worn away to the fang.

Fig. 19. Internal view of the relationship of the inferior teeth. *a*, Inner cutting edge of the triturating surfaces; *b*, teeth with the apical half of the crown worn away; *c*, an unworn tooth; *d*, tooth with the crown little more than half developed.

Figs. 20–23. Mutilated tooth of *Astrodon Johnstoni*, natural size, from Bladensburg, Md., belonging to Dr. C. Johnston.

Fig. 20. Outer view.

Fig. 21. Inner view.

Figs. 22, 23. Lateral views.

Figs. 24–26. Fragments of the jaws of *Hadrosaurus*, one-half the diameter of the originals.

Fig. 24. Inner view of a fragment of the lower jaw, exhibiting the alveolar grooves.

Fig. 25. Outer view of the same specimen, much mutilated.

Fig. 26. Inner view of a fragment supposed to belong to the upper jaw.

Figs. 27, 28. Supposed sacro-vertebral body of a young *Hadrosaurus*, from Monmouth Co., New Jersey, one-half the diameter of the original.

Fig. 27. Side view.

Fig. 28. Inferior view.

PLATE XIV.

Hadrosaurus Foulkii. Bones of the limbs, one-fourth the diameter of the originals.

Figs. 1–4. The left humerus.

Fig. 1. Posterior view.

Fig. 2. Anterior view.

Fig. 3. External view.

Fig. 4. Upper extremity. *a*, Head; *b*, internal tuberosity; *c*, external tuberosity; *d*, deltoid attachment.

Fig. 5. Anterior view of the left ulna.

Fig. 6. Anterior view of the left radius.

Figs. 7, 8. Metatarsal bone.
Fig. 7. Upper view.
Fig. 8. Lateral view.
Figs. 9, 10. Another metatarsal.
Fig. 9. Lateral view.
Fig. 10. Inferior view.
Figs. 11, 12. Phalanx.
Fig. 11. Upper view.
Fig. 12. Lateral view.

PLATE XV

Hadrosaurus Foulkii. Figures one-fourth the diameter of the original

Figs. 1–6. The left femur.
Fig. 1. Anterior view.
Fig. 2. External view.
Fig. 3. Internal view.
Fig. 4. Posterior view.
Fig. 5. Upper view.
Fig. 6. Lower view. *a,* Head; *b,* trochanter; *c,* process of the shaft; *d,* internal condyle; *e,* external condyle; *f,* canal between the condyles in front; *g,* canal between the condyles behind.

Figs. 7, 8. Lateral and superior views of a metatarsal bone, supposed to belong to the same animal, from Freehold, Monmouth County, New Jersey.

PLATE XVI.

Bones of the left leg of *Hadrosaurus* one-fourth the diameter of the originals.

Figs. 1–6. The tibia.
Fig. 1. Anterior view.
Fig. 2. Internal view.
Fig. 3. External view.
Fig. 4. Posterior view.
Fig. 5. View of the head from above.
Fig. 6. Inferior view of the tarsal extremity.
Figs. 7, 8. The fibula, without the upper extremity
Fig. 7. External view.
Fig. 8. Inferior view of the tarsal end.

PLATE XVII

Figs. 1–3. Left humerus, resembling that of *Hadrosaurus,* from Monmouth County, New Jersey, one-fourth the diameter of the original.

Fig. 1. Posterior view.
Fig. 2. Anterior view.
Fig. 3. External view.
Figs. 4, 5. Supposed ilium of *Hadrosaurus,* one-fourth the diameter of the original.
Fig. 4. Anterior view.
Fig. 5. Sacral border.

Figs. 6, 7. Fragments of a tibia, of *Coelosaurus,* from Monmouth County, one-half the diameter of the originals. From the collection of Mr. Willis.

Fig. 6. Fragment of the upper extremity.

Fig. 7. The lower extremity.

Figs. 8–11. Bones of the toes, found with the preceding fragments, one-half the diameter of the originals. From the collection of Mr. Willis.

Fig. 8. Lateral view of the fragment of a metatarsal bone.

Figs. 9, 10. Upper view of two phalanges.

Fig. 11. Lateral view of another phalanx.

Figs. 12, 13. *Mosasaurus*. From the Yellowstone River, Nebraska.

Fig. 12. Supposed ulna, one-half the diameter of the original.

Fig. 13. Phalanx, the size of nature.

PLATE XVIII.

Figs. 1–3. *Emys beatus*. From Gloucester Co., N. J. One-half the size of nature.

Fig. 1. Plates of the carapace. *a*, First vertebral plate; *b, c*, third and fourth vertebral plates; *d*, fragment of the first left costal plate; *e, g*, portions of the second and third right costal plates.

Fig. 2. Inner view of the second right costal fragment, exhibiting at *f* the rudiment of a costal process.

Fig. 3. First left marginal plate. The upper border of the figure is the outer or free margin of the specimen.

Figs. 4–8. *Bothremys Cookii*. The size of nature. From Gloucester Co., N. J. Collection of Prof. Cook.

Fig. 4. Lateral view of the skull.

Fig. 5. Lateral view of the mandible.

Fig. 6. Upper view of the skull.

Fig. 7. Inferior view of the skull. *a*, Deep funnel-shaped pit of the maxilla.

Fig. 8. Upper view of the mandible. *b*, Deep pit opposed to that of the upper jaw.

Fig. 9. Outer portion of a left costal plate of *Trionyx priscus*, of the natural size. From Monmouth County, N. J. Collection of Prof. Cook.

Fig. 10. Portions of two marginal plates of *Chelone ornata*, of the natural size. From Burlington County, N. J. The margin to the right is the free one.

Figs 11–14. Teeth of *Bottosaurus Harlani*, of the natural size. From Burlington County, New Jersey.

Fig. 11. Outer view of a tooth.

Fig. 12. Posterior view of the same.

Fig. 13. Outer view of a large tooth, belonging to the Burlington County Lyceum of Natural History.

Fig. 14. Outer view of a small tooth.

PLATE XIX.

Fig. 1. Plates of the sternum of *Emys pravus*, one-third the diameter of the original. From Tinton Falls, Monmouth County, New Jersey, and belonging to the collection of the New Jersey Geological Survey. *a*, Position of the entosternal bone; *b*, the right hyosternal bone; *c*, portion of the left hyposternal; *d*, position of the right hyposternal; *e, f*, fragments of both xiphisternals.

Figs. 2, 3. Plates of the carapace and sternum of *Emys firmus*, one-half the diameter of the originals. From Tinton Falls, Monmouth County, New Jersey, and belonging also to the preceding collection.

Fig. 2. Greater portions of the sixth and seventh marginal plates of the left side. *a*, Sixth; *b*, seventh marginal plate.

Fig. 3. Portions of the left hyosternal and right hyposternal plates. *a*, Position of the entosternal; *b*, left hyosternal, broken at its outer part; *c*, position of the right hyosternal; *d*, portion of the right hyposternal; *e*, position of left hyposternal; *f, g*, position of xiphisternals.

Fig. 4. Three marginal plates of the left side of *Platemys sulcatus*, one-half the diameter of the originals. From Tinton Falls, Monmouth County, New Jersey, and belonging to the same collection as the preceding.

Fig. 5. Four marginal plates of the left side of *Chelone sopita*, one-half the diameter of the originals. From Mullica Hill, Gloucester County, New Jersey. *a*, Portion of a marginal plate; *b, c, d,* the three succeeding plates; *e*, large notch between two of the plates; *f*, suture for articulation with the next plate; *g* rounded unarticulating border; *h*, inner border of the plates; *i*, outline of the scutes.

Fig. 6. Anterior extremity of the upper jaw of *Mosasaurus*, from Monmouth County, New Jersey, one-half the diameter of the original. From the collection of Rutgers College. *a*, Intermaxillary, occupied by two teeth on each side; *b*, portion of the right maxillary; *c*, fore part of the maxillary, imperfect; the space which was originally occupied by a tooth being now filled with an artificial cement.

Fig. 7. *Mosasauroid* tooth, natural size, from near Marion, Alabama. The specimen from which the tooth was drawn belongs to the Smithsonian Institution, and strongly resembles, in general appearance, *Mosasauroid* fossils from near Columbus, Mississippi.

Fig. 8. Tooth of *Piratosaurus plicatus*, of the size of the original. From the Red River of the North, and belonging to the collection of the Smithsonian Institution.

PLATE XX.

Fig. 1. Transverse section of a tooth of *Hadrosaurus Foulkii*, highly magnified. *a*, Enamel; *b*, isolated streak of the same; *c*, the interior dentine; *d*, exterior layer of vaso-dentine.

Fig. 2. Transverse section of a small portion of the vaso-dentine of the tooth of *Hadrosaurus*, more highly magnified. *a*, The dentine; *b*, network of vaso-dentinal tissue.

Fig. 3. Diagram representing the arrangement of structure seen in a vertical section of the teeth of *Mosasaurus*. *a*, The crown, composed of interior dentine with a thin investment of enamel; *b*, the fang, composed of cementum; *c*, the pulp cavity; *d*, the communication of the latter with the exterior occupied by a coarser structure of cementum, pervaded by large vaso-neural canals; *e*, line of cessation of the dentine; *f*, cavity for a successional tooth; *g*, position from which the section was taken forming the subject of the next figure.

Fig. 4. Section from the tooth of *Mosasaurus*, taken from the position marked *g* in the preceding figure, and highly magnified. *a*, dentine of the crown; *b*, cement of the fang.

Fig. 5. A smaller section similar to the last, more highly magnified. *a*, dentine; *b*, cement.

Fig. 6. A similar section still more highly magnified. *a*, dentine; *b*, cement.

Figs. 7–9. Tooth of *Tomodon horrificus*, from Mullica Hill, Gloucester County, New Jersey, of the natural size.

Fig. 7. Outer view.

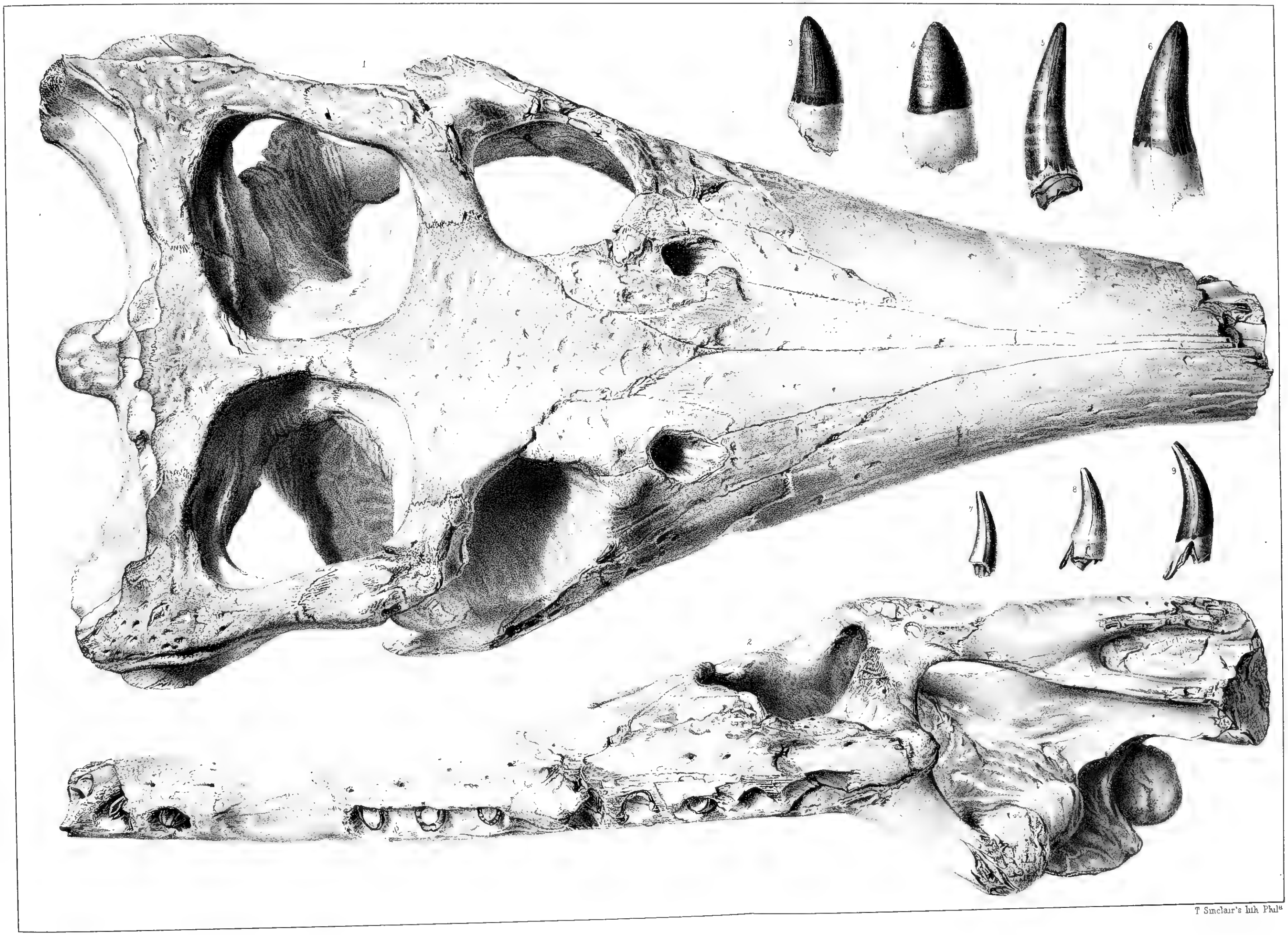
Fig. 8. Inner view.

Fig. 9. Lateral view.

Fig. 10. Transverse section of the tooth of *Astrodon Johnstoni*, highly magrified, from a preparation made and loaned by Dr. Christopher Johnston.

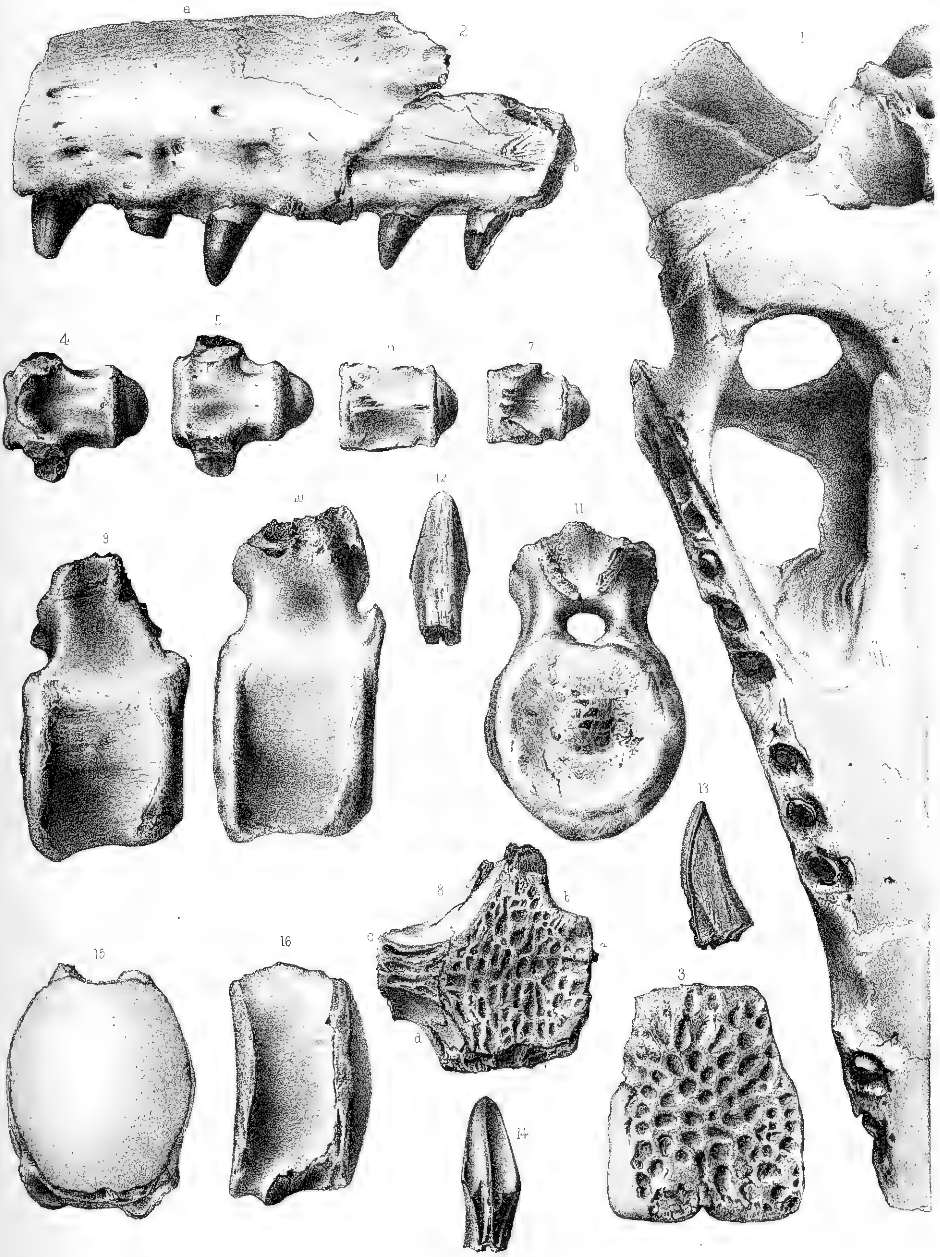
PUBLISHED BY THE SMITHSONIAN INSTITUTION,
WASHINGTON CITY,
MAY, 1865.

Plate I



T Sinclair's lith Phil^a

1-6. THORACOSAURUS NEOCESARIENSIS 7-9. GAVIAL, from New Jersey.

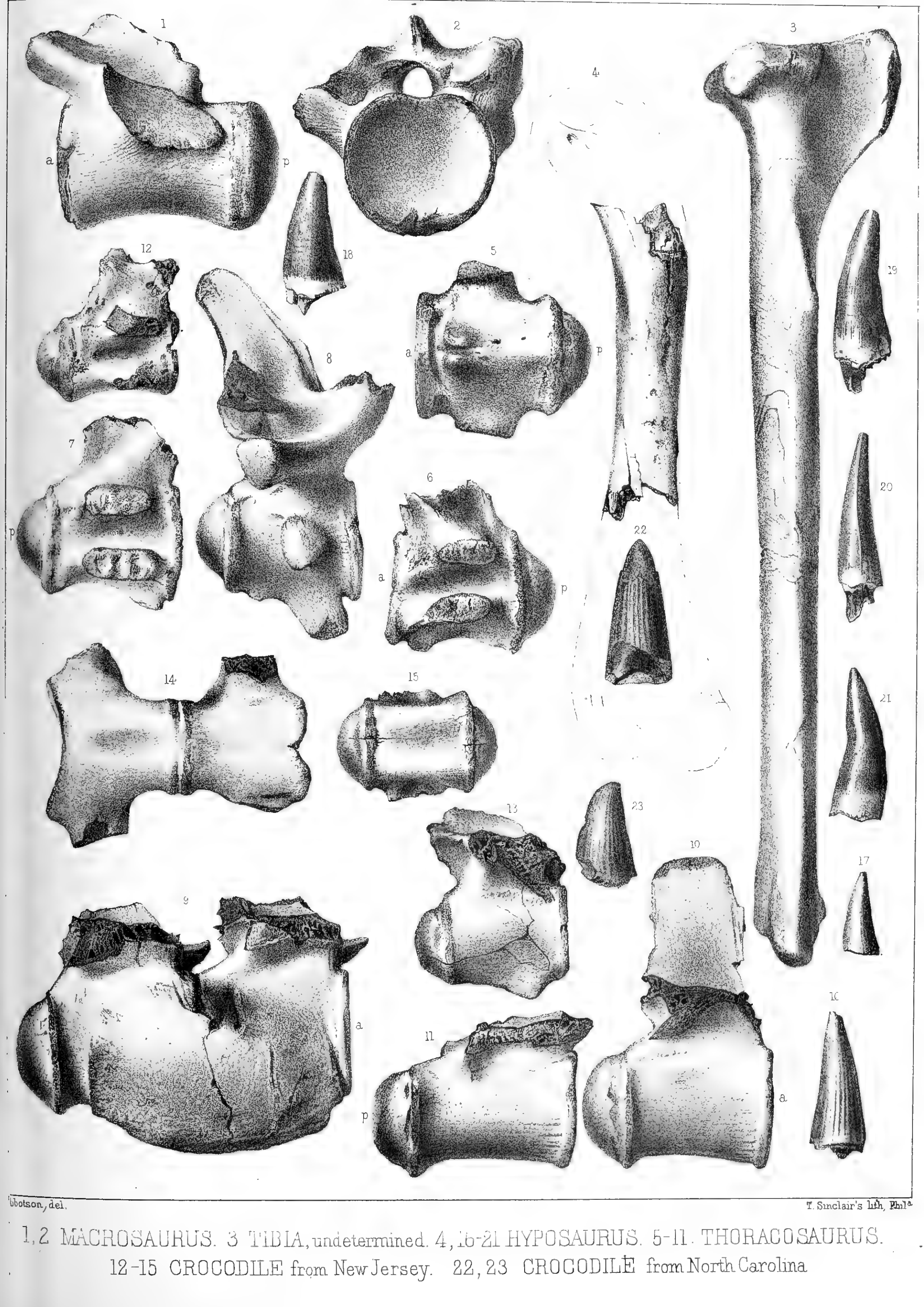


Ibbotson, del

T. Sinclair's lith, Phila

1-3. THORACOSAURUS. 4-8 CROCODILES. 9-11. HADROSAURUS
12-14 TRACHODON. 15-16 Undetermined

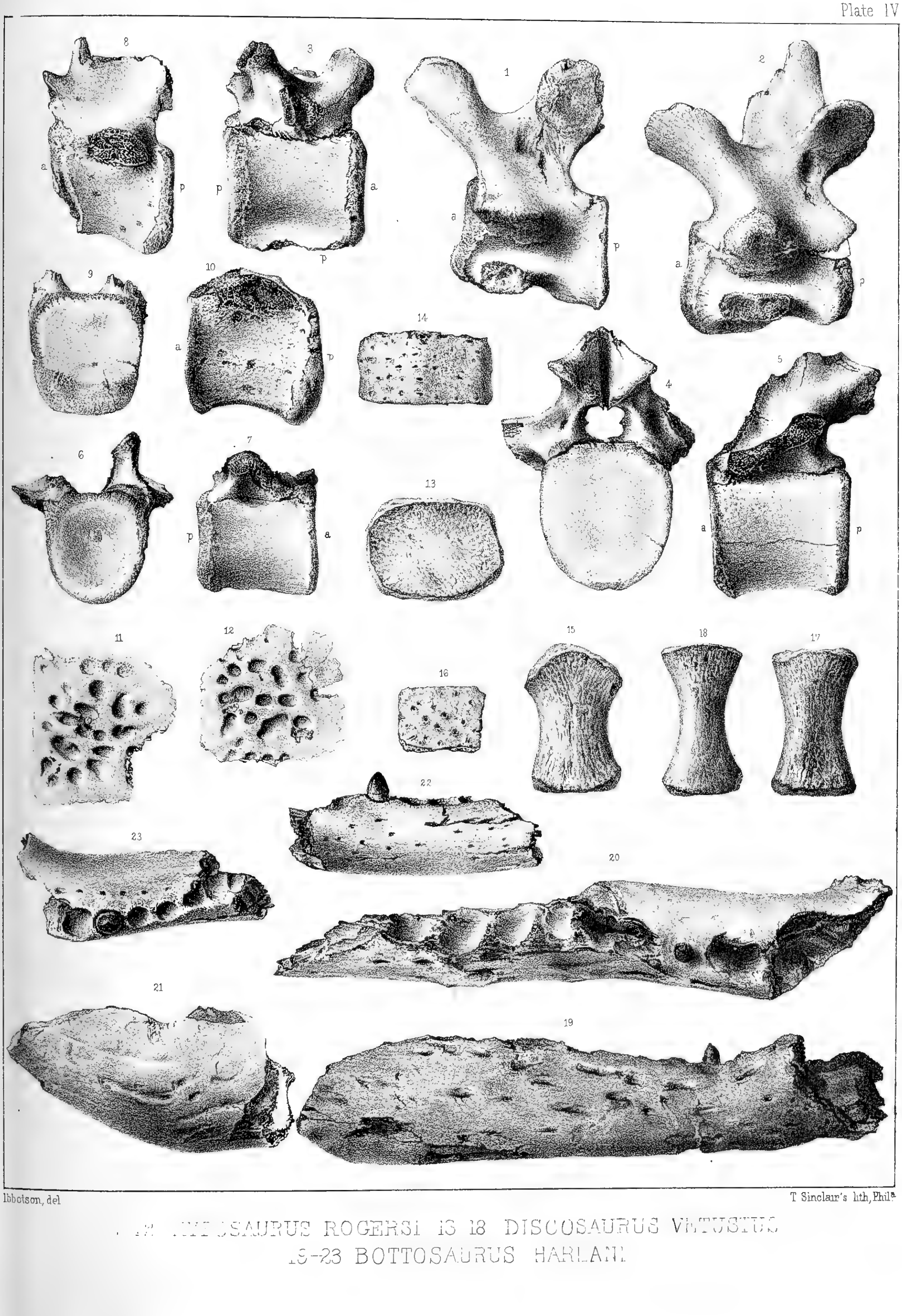
Plate III



ibbotson, del.

T. Sinclair's lith, Phil^a.

1, 2 MACROSAURUS. 3 TIBIA, undetermined. 4, 16-21 HYPOSAURUS. 5-11. THORACOSAURUS.
12-15 CROCODILE from New Jersey. 22, 23 CROCODILE from North Carolina

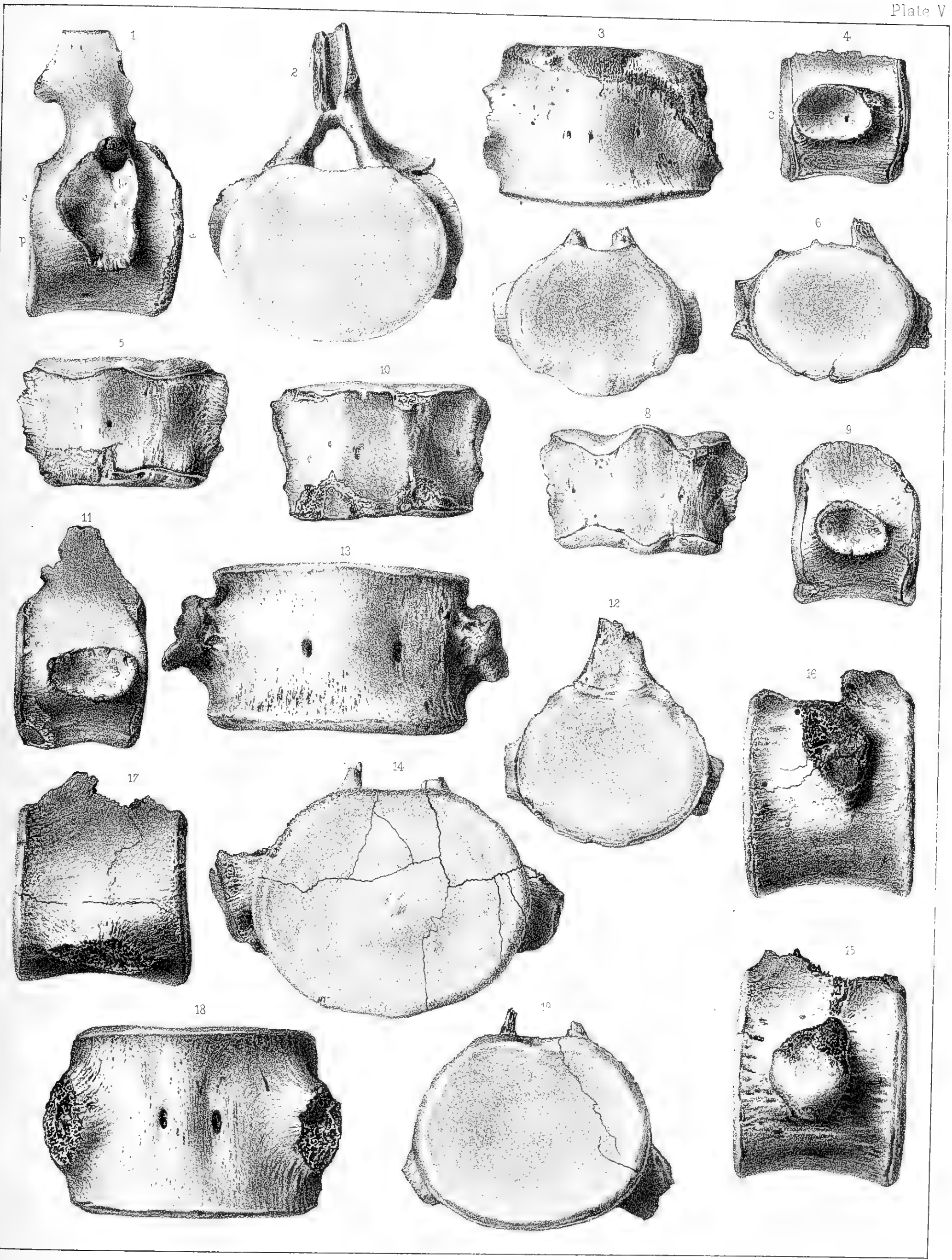


Ibbotson, del

T Sinclair's lith, Phil^{a}

1-12 HYPOSAURUS ROGERSI. 13-18 DISCOSAURUS VETUSTUS.
19-23 BOTTOSAURUS HARLANI.

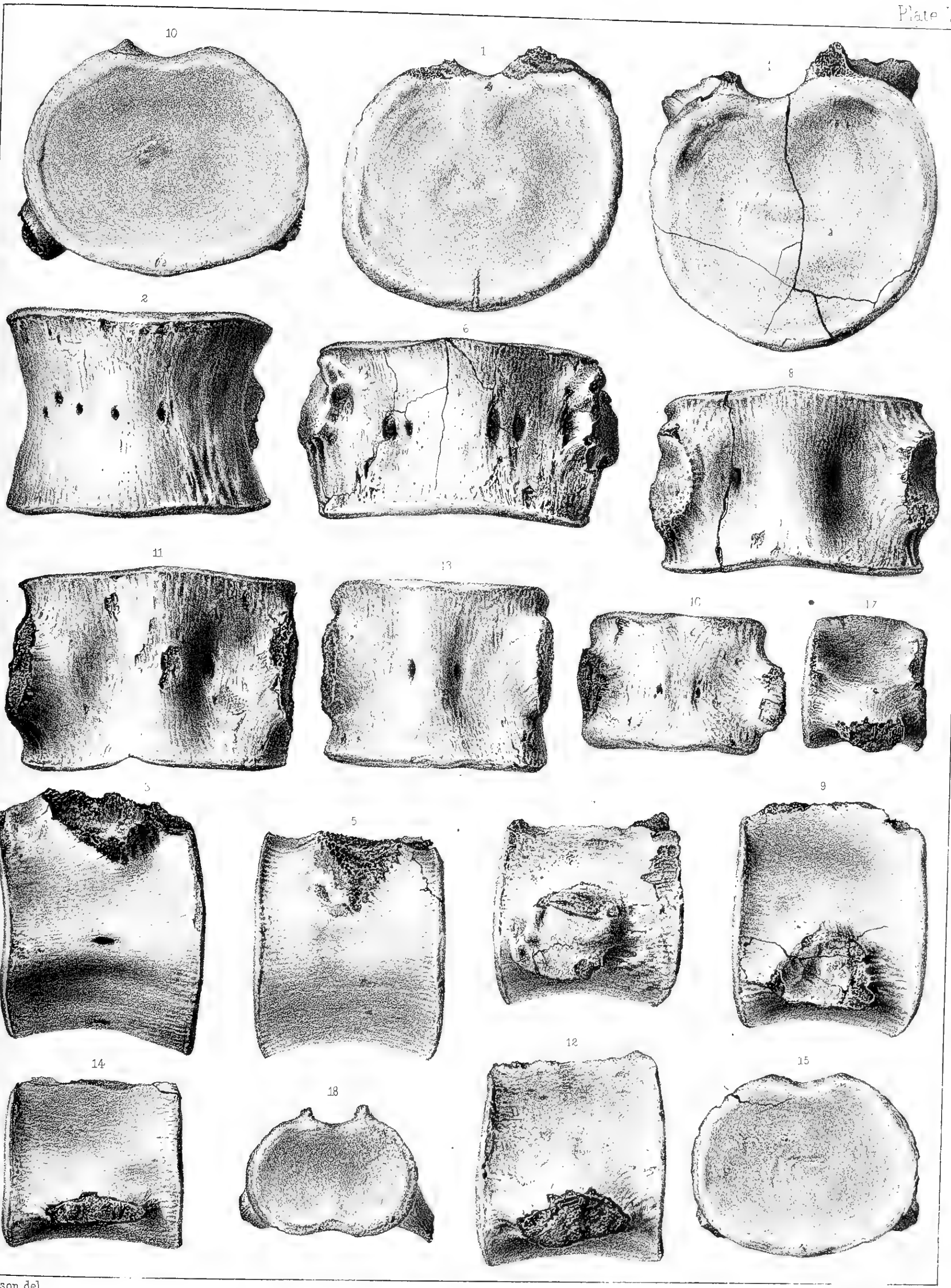
Plate V



T. Sinclair's lith. Phil^a

1–12 DISCOSAURUS VETUSTUS. 13–19 CIMOLIASAURUS MAGNUS

Plate VI



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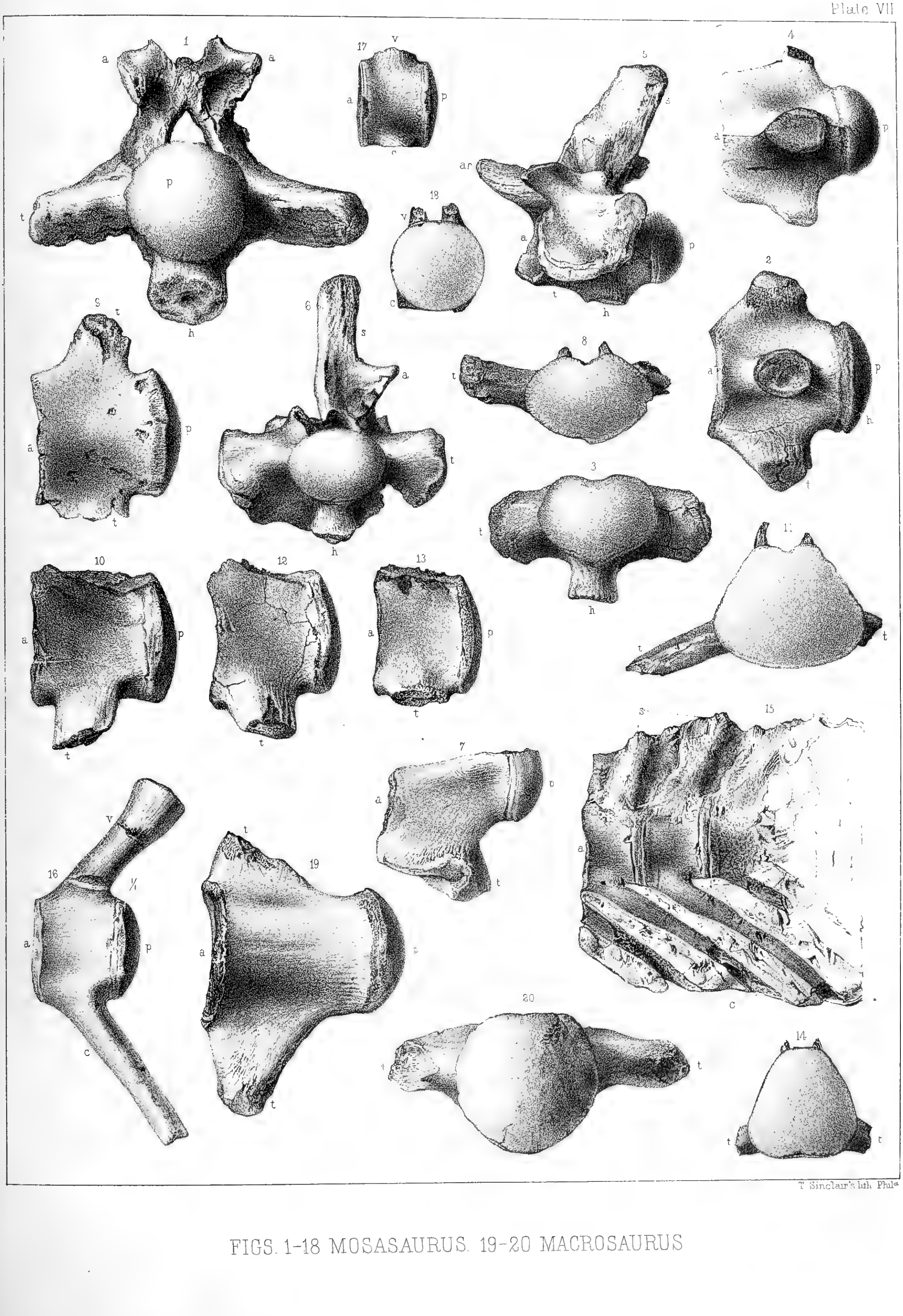
T. Sinclair's lith, Phil^a

CIMOLIASAURUS MAGNUS.

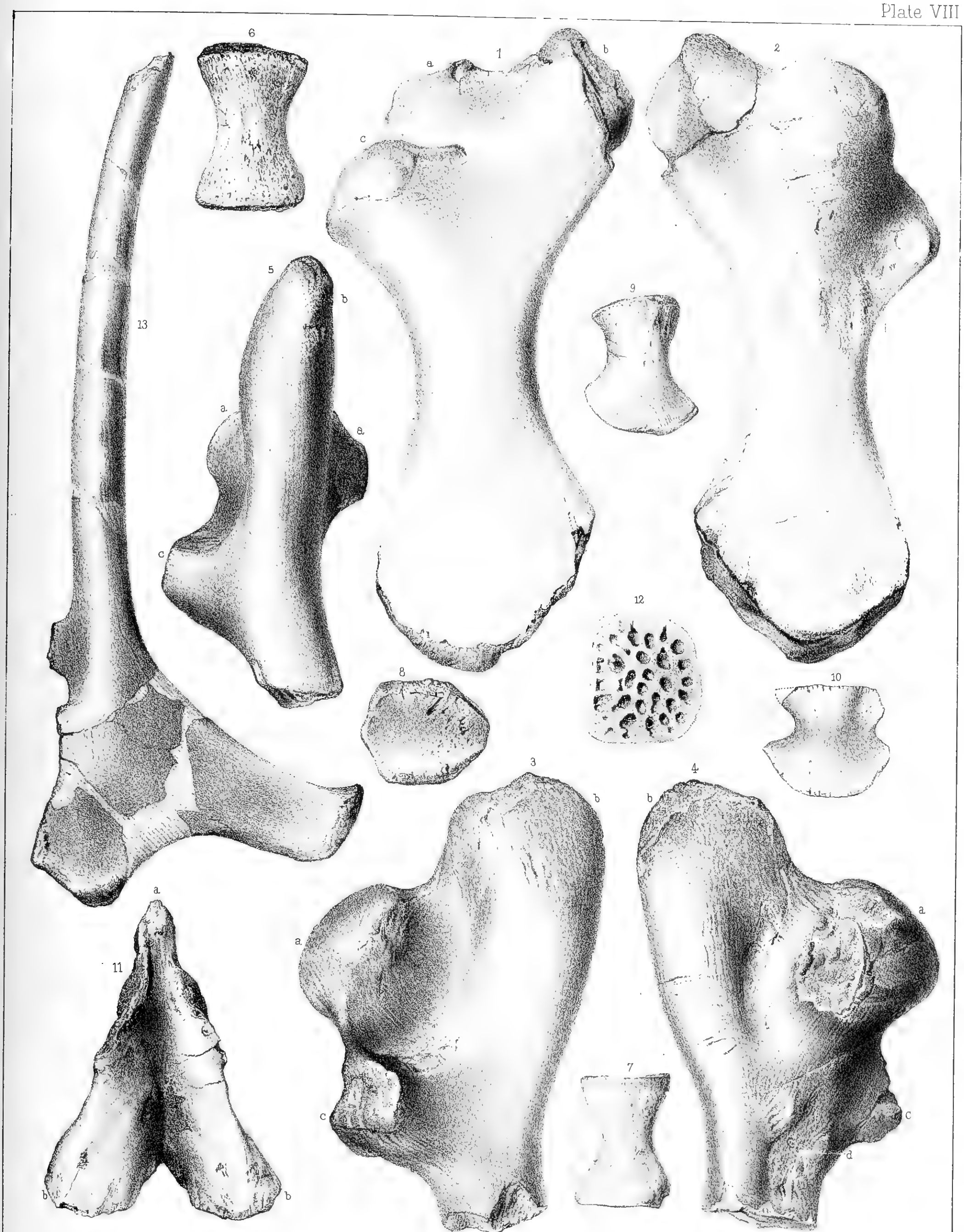
Plate VII



T. Sinclair's lith. Phila

FIGS. 1-18 MOSASAURUS. 19-20 MACROSAURUS

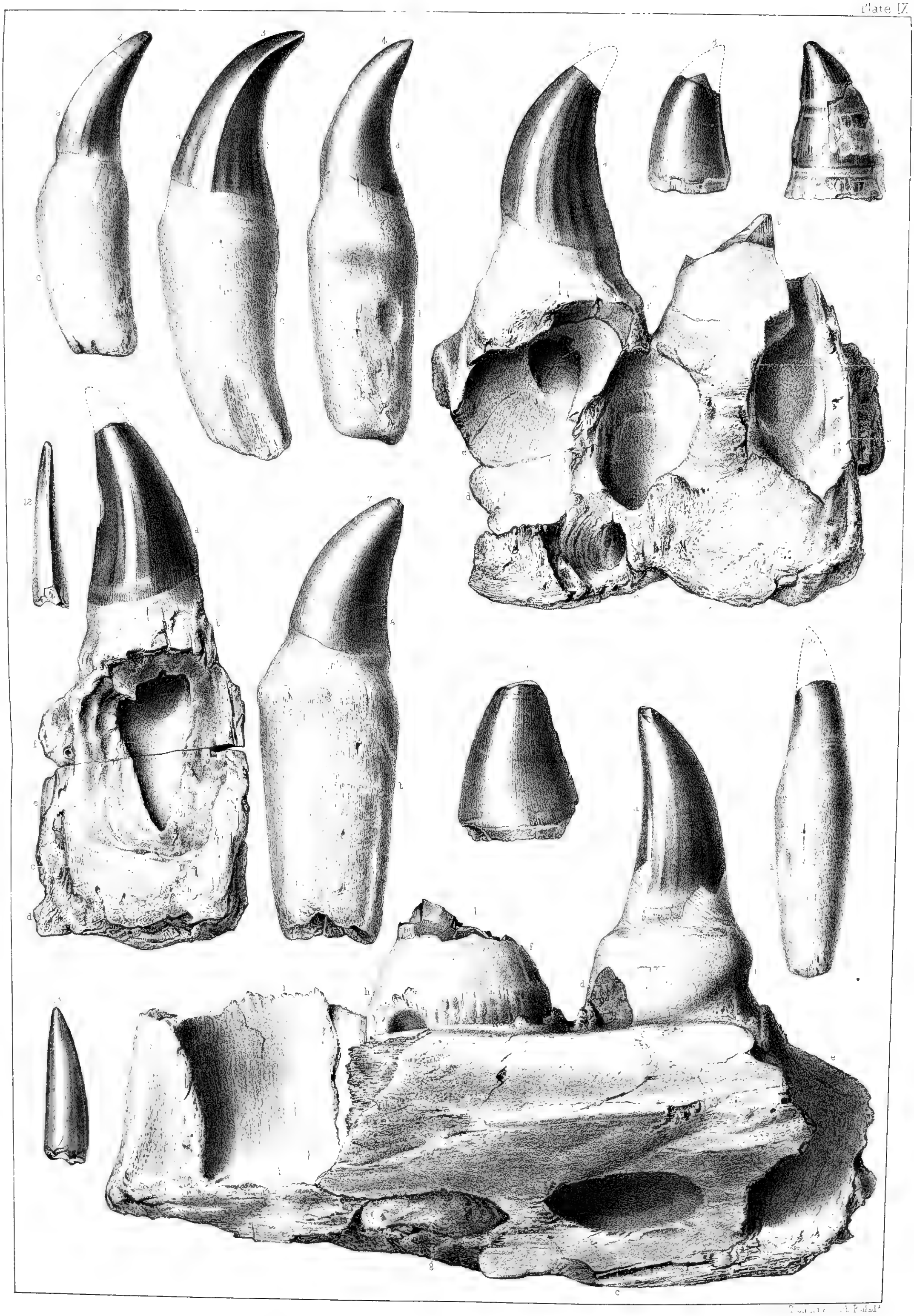
Plate VIII



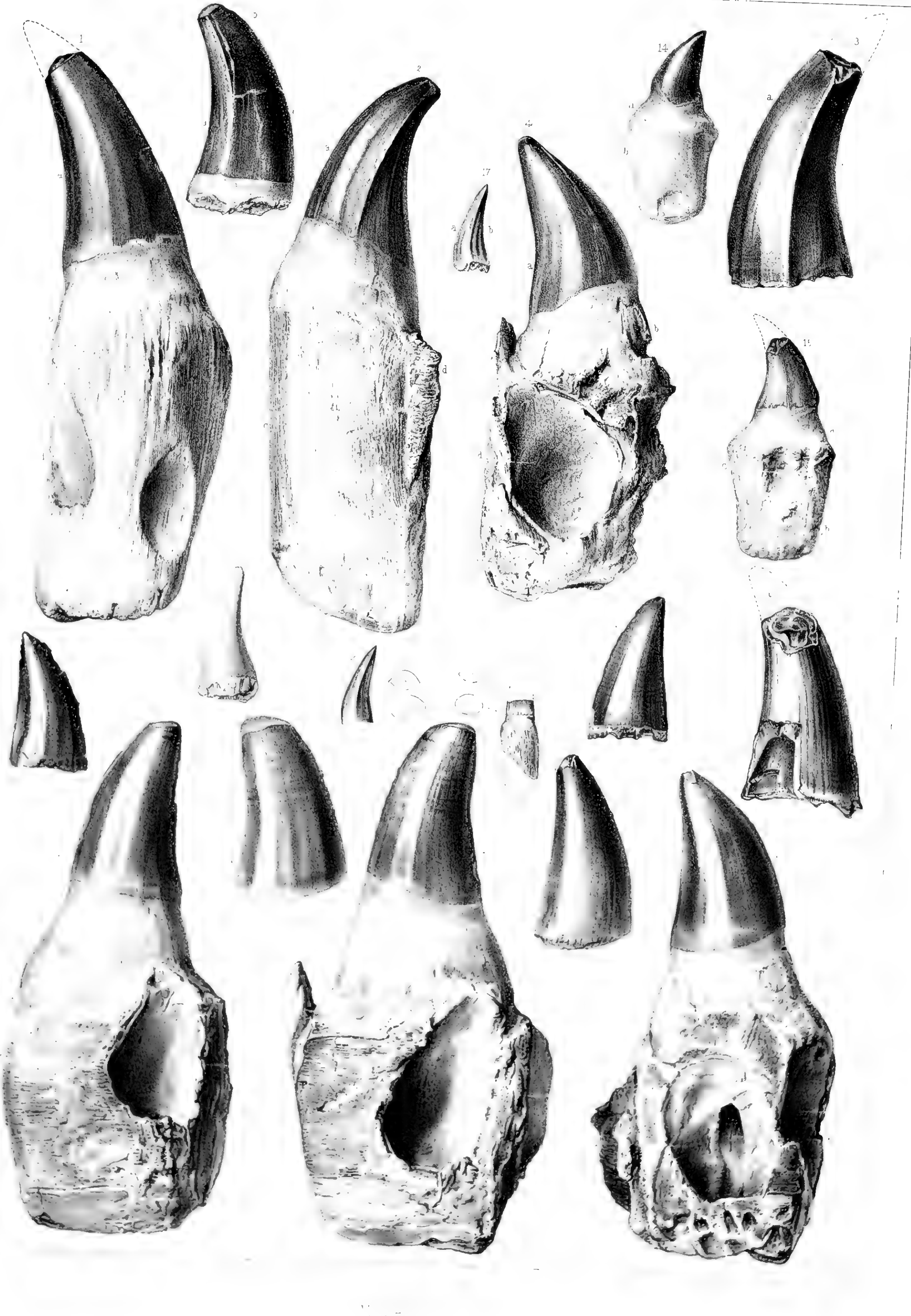
T. Sinclair's lith. Phila

1-11 MOSASAURUS. 12 GAVIAL. 13 HADROSAURUS.

Plate IX



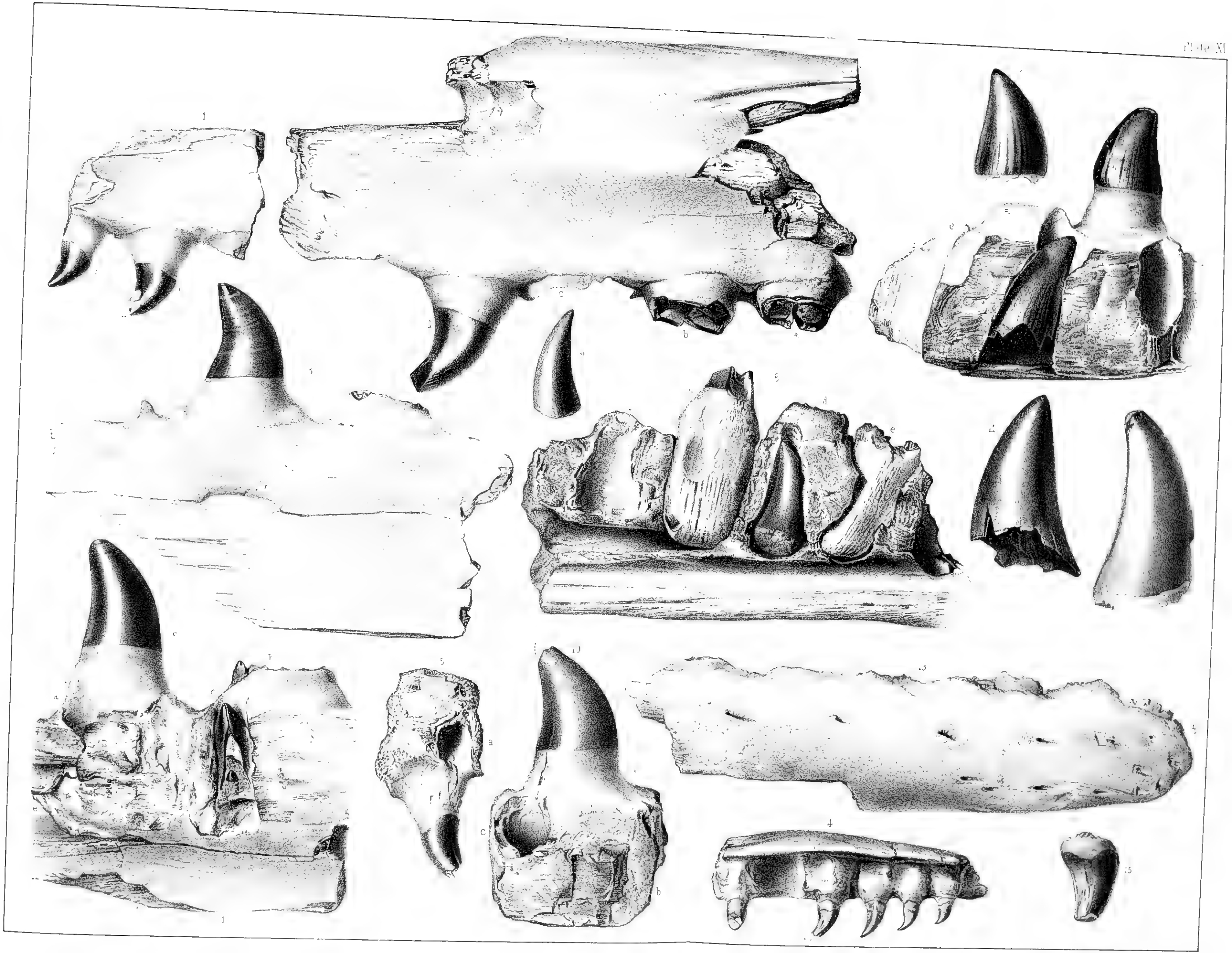
1-11 MOSASAURUS. 12-13 POLYGONODON VETUS


1
5
2
a
17
a
b
4
a
b
d
14
a
b
3
a
15

I

Phila

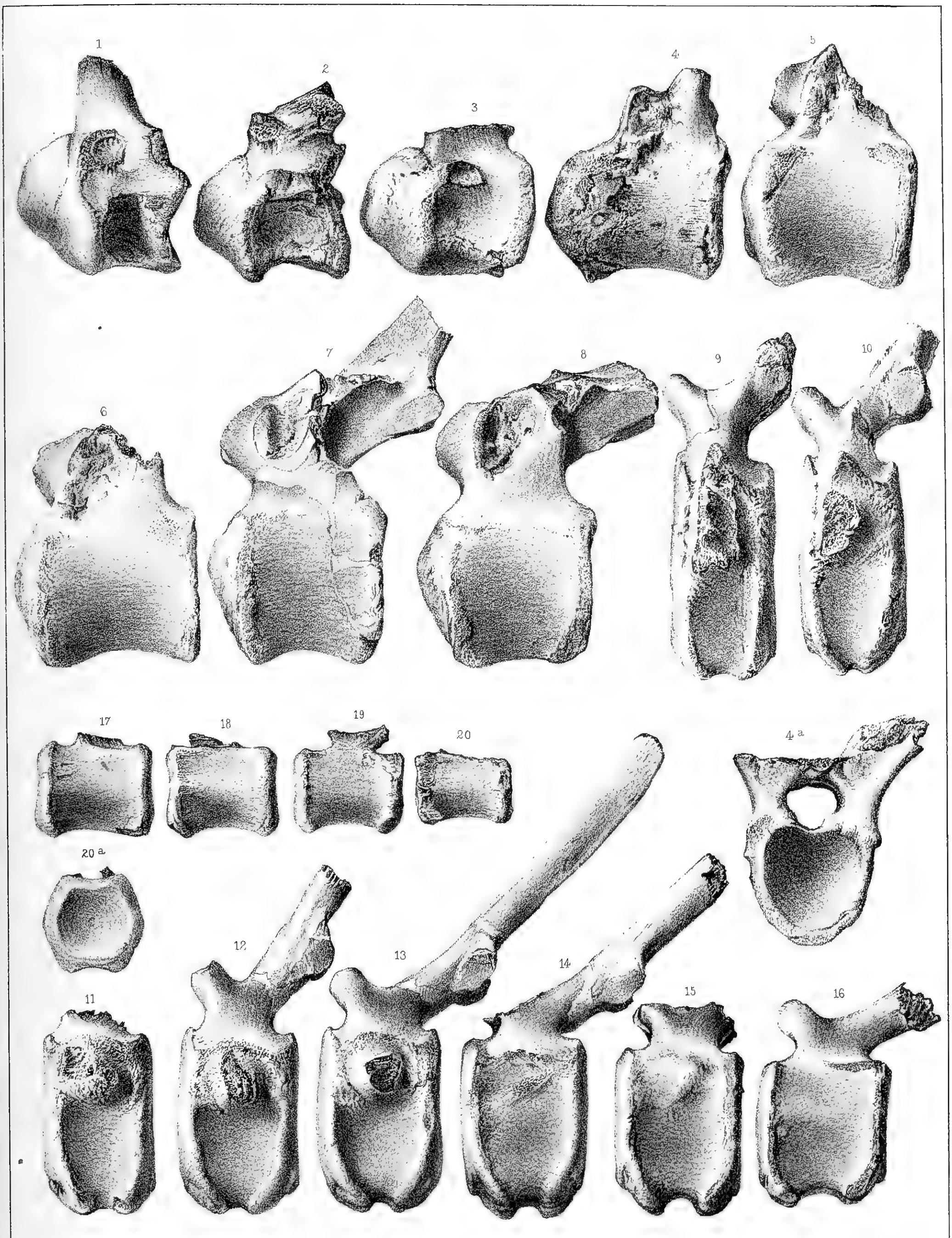
Plate XI



Sinclair's lith. Philad^a

MOSASAURUS

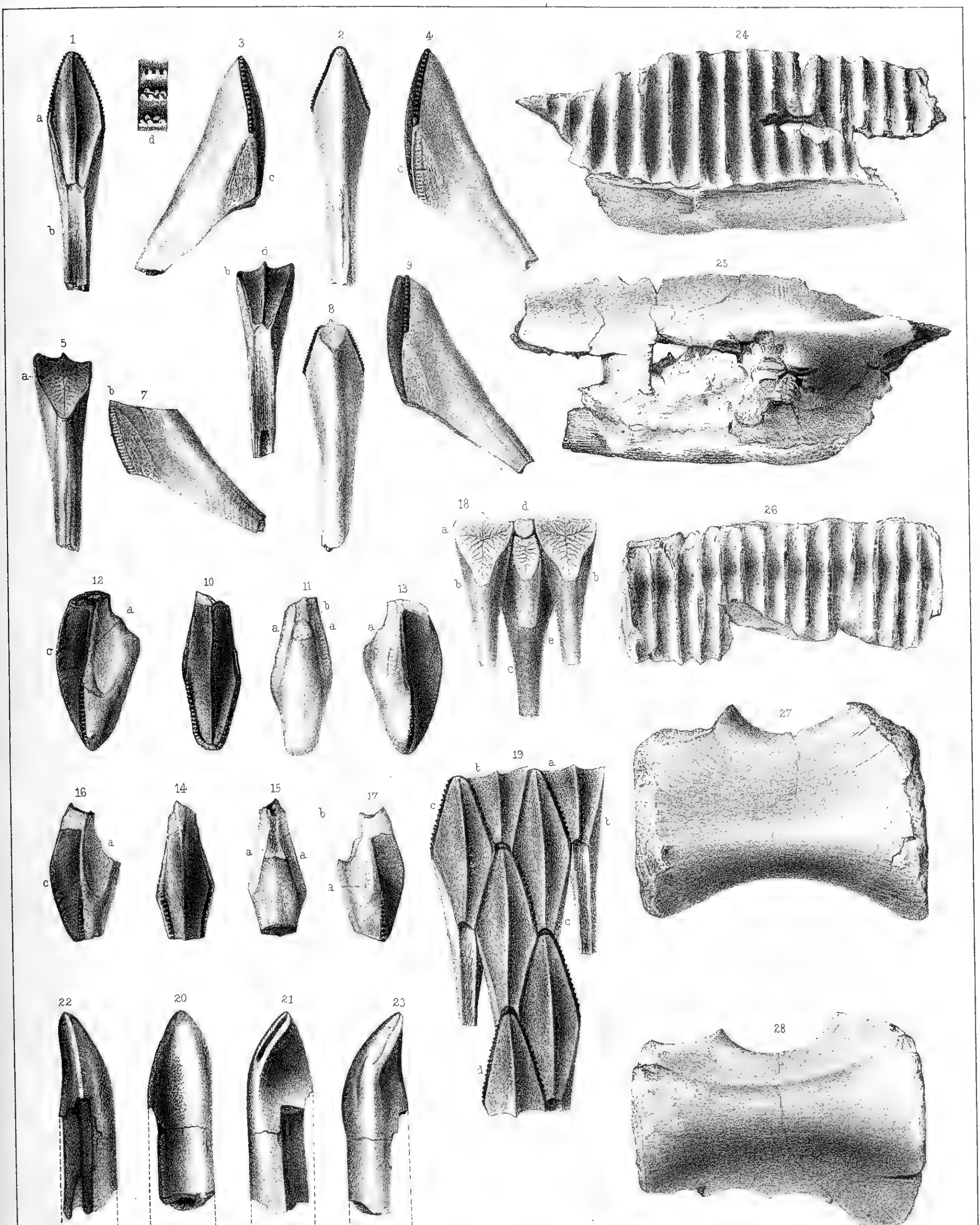
Plate XII



T. Sinclair's lith. Phila

HADROSAURUS FOULKII.

Plate XIII

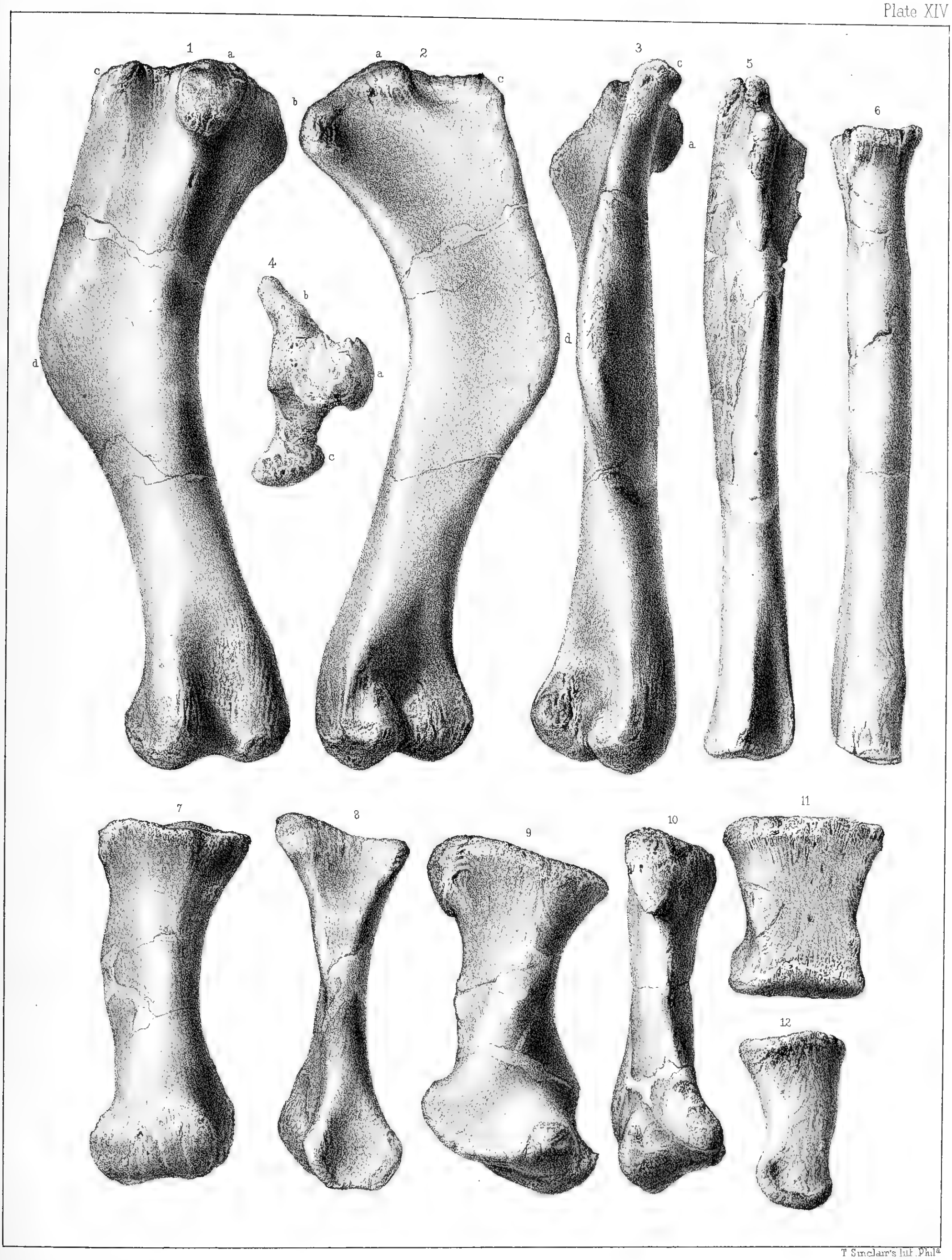


Dr. Leidy & Ibbotson, del

T Sinclair's lith, Philada

1-19, 24-28 HADROSAURUS. 20-23 ASTRODON.

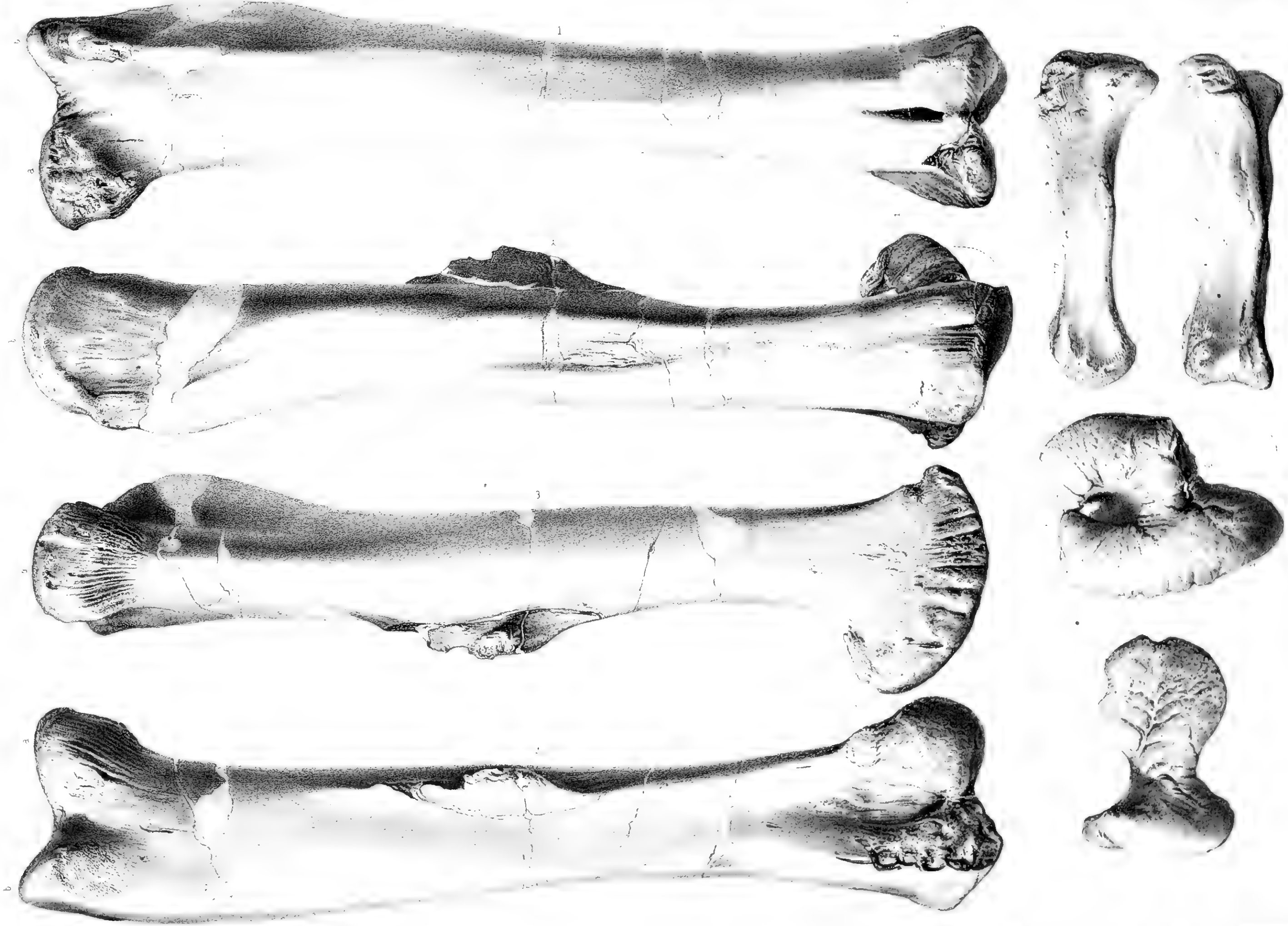
Plate XIV



T. Sinclair's lith. Phil^a

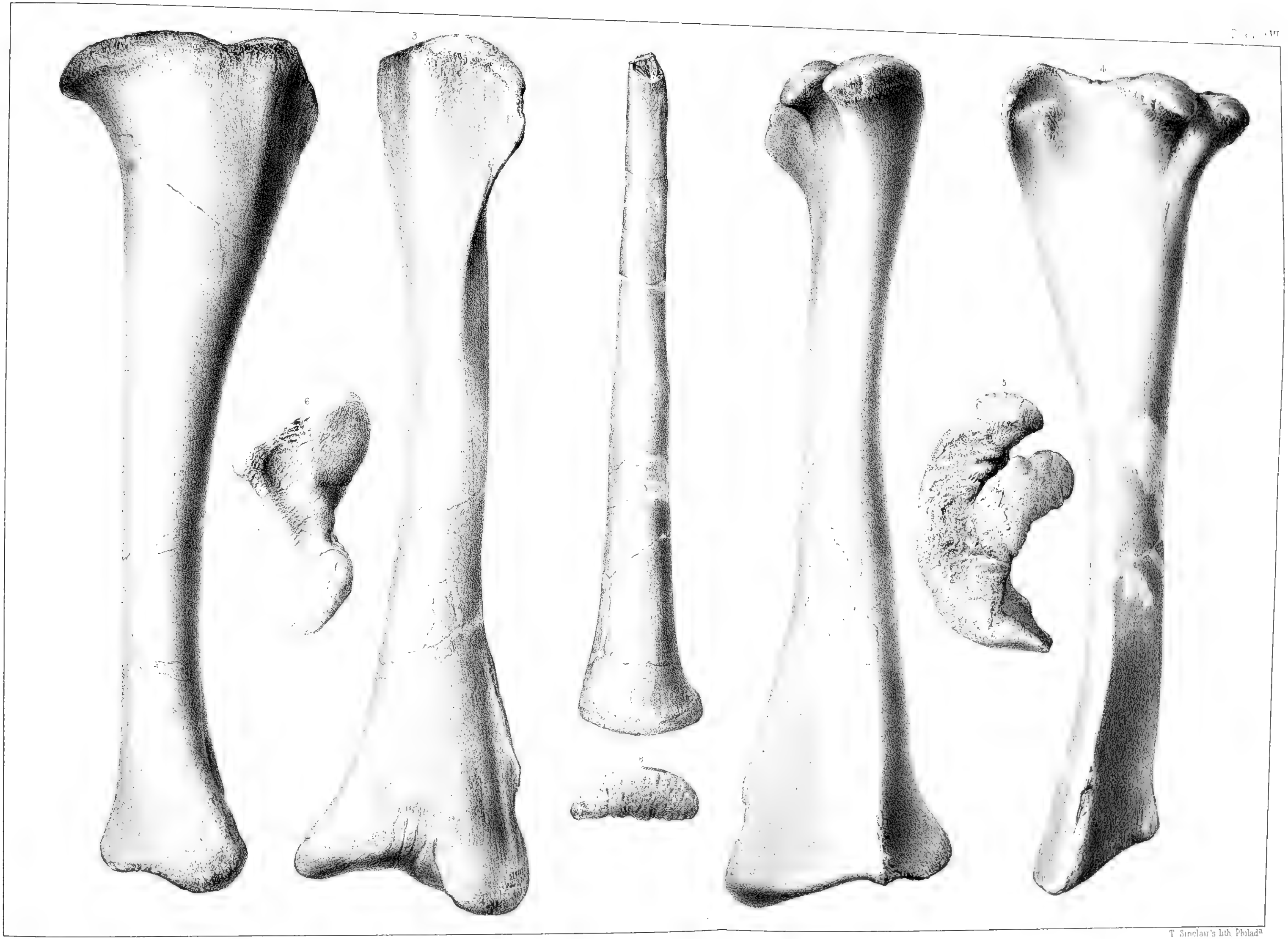
HADROSAURUS FOULKII

Plate XV



T. Sinclair's Lith. Ph.

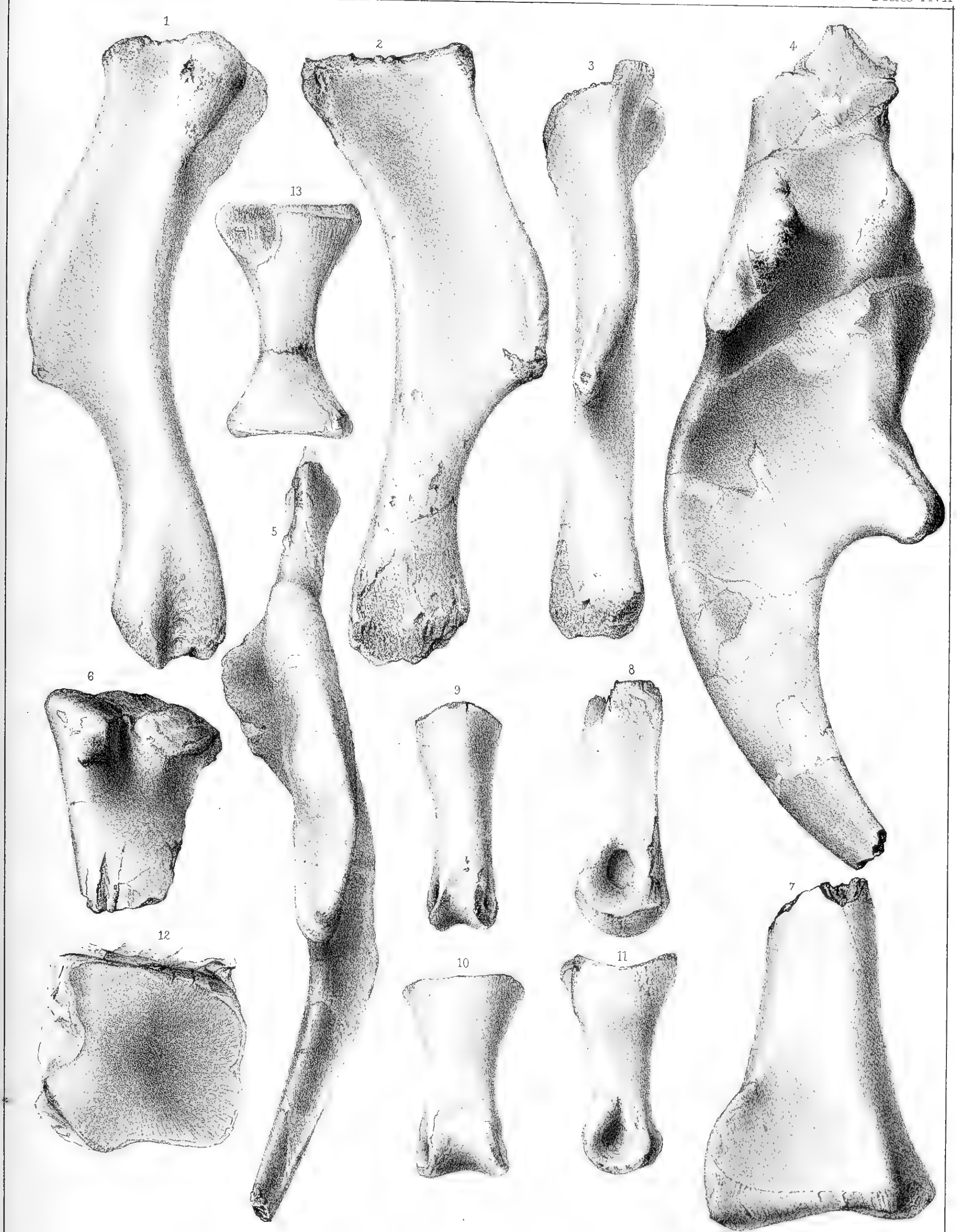
HADROSAURUS FOULKII



A J Ibbotson del

T Sinclair's lith Philad^a

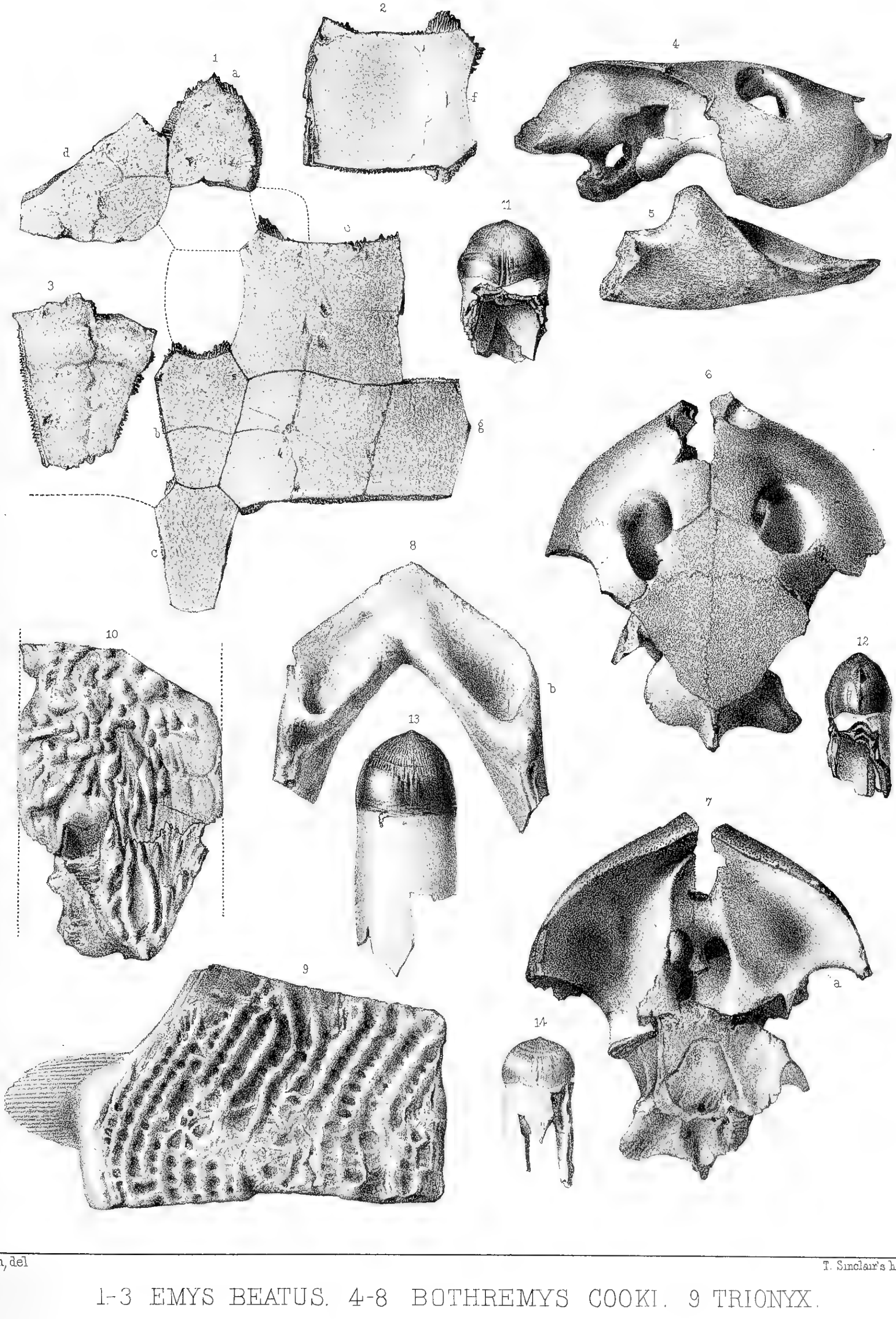
HADROSAURUS FOULKII



T. Sinclair's lith, Phil^a.

1-3 HUMERUS. undetermined. 4-5 HADROSAURUS. 6-11 undetermined. 12 MOSASAURUS.

Plate XVIII

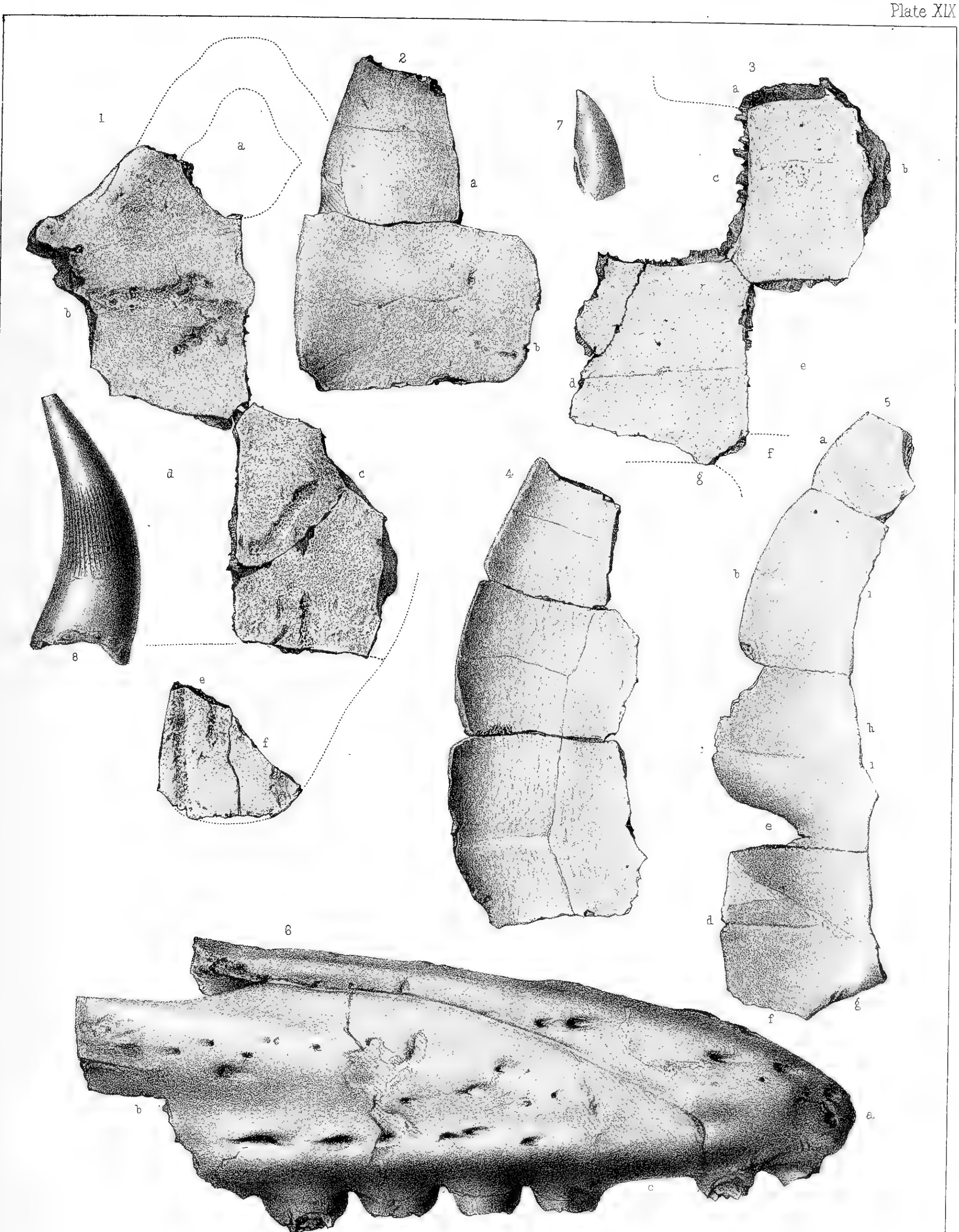


Ibbotson, del

T. Sinclair's lith, Phila.

1-3 EMYS BEATUS. 4-8 BOTHREMYS COOKI. 9 TRIONYX.
10 CHELONE. 11-14 BOTTOSAURUS.

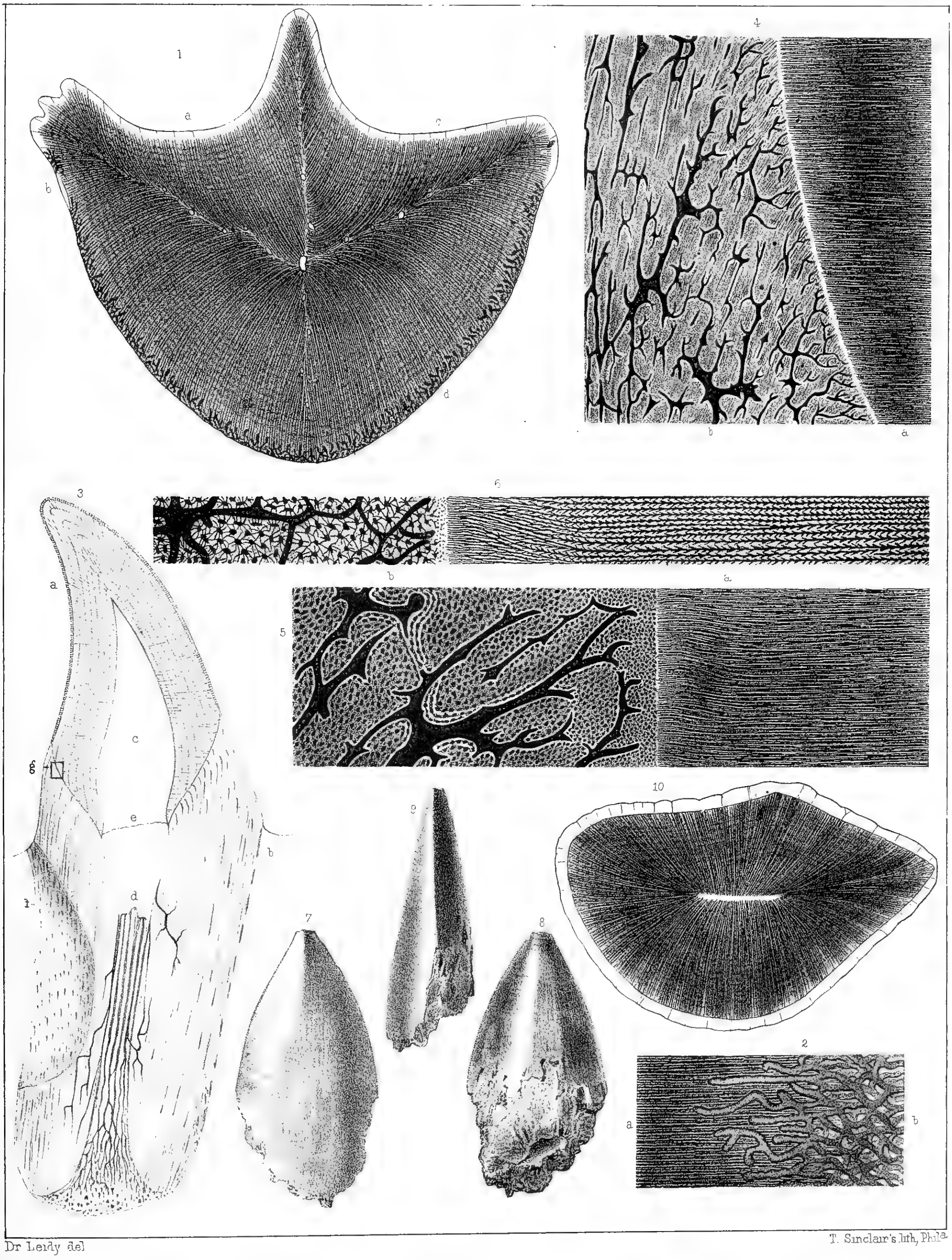
Plate XIX



Ibbotson, del.

T. Sinclair's lith. Phil^a

1 EMYS PRAVUS. 2,3 E. FIRMUS. 4 PLATEMYS SULCATUS.
5 CHELONE SOPITA. 6,7 MOSASAURUS. 8 PIRATOSAURUS.



Dr Leidy del

T. Sinclair's lith, Phil^a.

1, 2 HADROSAURUS. 3-6 MOSASAURUS. 7-9. TOMODON. 10 ASTRODON.