Theodore Lyman

MEMOIRS

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MEMOIRS

READ BEFORE THE BOSTON SOCIETY OF NATURAL HISTORY.

I. *Revision of the* Polypi *of the Eastern Coast of the United States.* *By* A. E. VERRILL.

Read November 19th, 1862.

THE Polyps of this coast have hitherto been less studied than the representatives of most other classes, and, up to the present time, there has been no attempt made to bring together in a systematic form the species that have been at various times described, both in this country and in Europe. Many of these have, however, long since found their natural positions in the general systematic works of Ellis,[1] Pallas,[2] Lamarck,[3] Lamouroux,[4] Cuvier,[5] Milne-Edwards,[6] and other distinguished naturalists of Europe, and in the magnificent work of Dana,[7] published by our own government. Besides these references, often very brief and imperfect, disconnected notices and descriptions of other species are found scattered through many volumes of the Proceedings and Journals of our scientific societies and associations.

But these materials, owing to their inaccessibility, and, in many cases, to their original imperfection, have not been made available either for scientific study and comparison with the European species, which have been carefully examined during many years, or to incite local naturalists and collectors to more careful studies of the habits and structure of these beautiful and interesting beings, and more thorough search for other forms.

It was for the purpose of supplying in some measure the deficiency in these respects, and to establish a basis for future investigations, rather than to present anything new, that the present work was undertaken; but, on account of the constant accessions of new materials, it has now become necessary to present quite a number of undescribed species, and it is very probable that many more remain to be hereafter discovered. I have also deemed it useful to introduce brief descriptions of the higher groups and their principal subdivisions, even in some cases when they were extralimital, in order to illustrate more clearly the position and zoölogical affinities of the species described. To do this I

1 John Ellis. Essay towards a Natural History of Corallines, 4to, London, 1754; Natural History of many curious and uncommon Zoöphytes, 4to, London, 1786. (Edited by Solander.)

2 Petrus Simon Pallas. Elenchus Zoophytorum, 8vo, Leyden, 1766.

3 Jean-Baptiste Lamarck. Histoire naturelle des animaux sans vertèbres, 8vo, Paris, 1815–22; 2d edition, 1836.

4 J. V. F. Lamouroux. Histoire générale des Polypiers coralligènes flexibles, 8vo, Caen, 1816.

5 Georges Cuvier. Règne Animal, t. iv., Paris, 1817; 2d edition, t. iii., 1830.

6 H. Milne-Edwards. Histoire naturelle des Coralliaires ou Polypes proprement dits. 3 vols. 8vo, Paris, 1857.

7 James D. Dana. United States Exploring Expedition under Capt. Wilkes. Zoöphytes, 4to, with folio plates, Philadelphia, 1846; plates, 1849.

have found it necessary to introduce many changes in the generally received systems of classification, — a result due in part to the investigations of the living coral-polyps by Prof. Agassiz, while in Florida, and partly to my own special studies of this class, while arranging and classifying the unrivalled collection in the Museum of Comparative Zoölogy. Although many of the results of the observations of Prof. Agassiz have as yet been made public only through his lectures, I have, in every case, endeavored to give the true authority for those conclusions that are not original with me.

In the preparation of this paper, I have been greatly indebted to Prof. Agassiz, who has not only allowed me the unrestricted use of the extensive collection of the museum, but has also, with characteristic liberality, placed in my hands his magnificent series of drawings, made from life by Mr. J. Burkhardt. These have been of the utmost value, especially in preparing the descriptions of the southern *Actinidæ*, of which I have had no opportunity to examine living specimens. I am also under many obligations to Mr. William Stimpson, who has furnished me with an elegant drawing of *Halcampa producta*, and with valuable notes concerning other species. To Mr. E. S. Morse, my thanks are due for my first opportunity to examine living specimens of *Bunodes stella*, and for several beautiful drawings of that species and of *Edwardsia sipunculoides*, some of which are reproduced in the accompanying plate.

Order I. ALCYONARIA.

The class of Polyps has undergone many changes, as it has been found necessary, from time to time, to remove groups belonging to other classes, confounded with it so long as their structure was imperfectly understood. The true polyps were for the first time divided into the two natural orders characterized by the number and structure of the tentacles, by Milne-Edwards and Audouin, in 1828, but at that time no special names were applied to the two groups thus established.

The name *Alcyonaria* (Alcyoniens) was given to the first of these divisions by Milne-Edwards,[1] in 1834.

In this order the polyps are more or less cylindrical, made up with eight nearly equal, hollow, elongated spheromeres arranged around the vertical axis and intimately united to each other by their sides, without the interposition of interambulacral spaces. All of them are prolonged at the actinal end into broad tentacles, pinnately lobed along their sides.

The second order, *Zoantharia*, has, on the contrary, spheromeres in multiples of six, often very numerous, united so as to leave interambulacral spaces in which the new ones are developed. The tentacles are simple, and generally cylindrical or conical, rarely branching in a furcate manner.

In the great work of Dana, the *Alcyonaria* have the same limits, but are considered as a sub-order of the order *Actinoidea*, — a group which embraces the whole class of Polyps as now restricted, his order *Hydroidea* having been referred more recently to the class of *Acalephs*.

The *Alcyonaria* have been divided by most modern writers into three natural groups.

I. Alcyonidæ; these are tubular and usually much elongated polyps, increasing by lateral or basal gemmation, forming communities by the union of the walls, their bases or appendices, sometimes, also, through the medium of a porous cœnenchyma, and therefore communicating by irregular pores and cavities. There is no common, specialized,

[1] Elémens de Zoologie, p. 1046. 1834.

central cavity or central axis, and the polyps adhere to foreign bodies directly by their bases or by the cœnenchyma.

II. GORGONIDÆ; in this group the polyps are short, cylindrical; connected laterally by a porous cœnenchyma, at their bases by a common membrane, and by specialized longitudinal canals; and arranged around a firm central axis which is secreted from the common basal membrane. The communities are attached to foreign bodies by the expanded base of the central axis.

III. PENNATULIDÆ; this division includes those that are united into communities which are unattached and capable of voluntary locomotion. The polyps are regularly arranged at the upper part of the structure, which contains special ducts and a central cavity, sometimes subdivided or inclosing a solid axis attached to the walls by muscular fibres. The lower extremity is bulbular and capable of expansion and contraction by means of a well-developed common muscular system.

The nature and rank of these three groups have been variously estimated by naturalists. Milne-Edwards, who is among the highest authorities, in his latest works treats them as families. But since they are characterized by modifications of the most important structures beneath those characteristic of the order, and at the same time include other inferior groups that have the nature of families, I am led to consider them as sub-orders.

Sub-order I. ALCYONIDÆ.

The characters of this division have been sufficiently indicated above for our present purpose. It embraces several well-marked families; viz: *Alcyoninæ* Ehr. (restricted), *Xeninæ* Ehr., *Cornularinæ* Ehr. (emended), *Tubiporidæ* Fleming. Of these, *Alcyoninæ* and *Cornularinæ* are alone represented on our coast, so far as at present known.

Family ALCYONINÆ Ehrenberg.

Alcyonidæ (*pars*) DANA, Zoöphytes. *Alcyoninæ* (*pars*) MILNE-EDWARDS, Coralliaires.

In this family the polyps are united together by the walls or porous cœnenchyma throughout nearly their whole extent, forming massive lobed or arborescent clusters of fleshy or coriaceous texture, filled with calcareous spicula. The tentacles and upper free portion of the polyps are capable of more or less perfect contraction.

This family has been divided by Milne-Edwards into two groups: 1st, *Alcyoniens nus*, corresponding to *Alcyoninæ* of Dana; 2d, *Alcyoniens armés*, corresponding to *Nephtheæ* Lesson and, in part, to *Spoggodinæ* Dana.

ALCYONIUM Linn.

Alcyonium LINNÆUS, Syst. Nat., edit. x. vol. i. p. 803, (1758). *Mazina* OKEN, Lehrb. der Nat., t. iii. p. 93, (1815). *Lobularia* SAVIGNY, (Lamk. Hist. An. sans Vert. 1816); EHRENBERG, Corall. des roth. Meer., p. 57, (1834). *Alcyonium* DANA, Zoöph., p. 611, (1846); MILNE-EDWARDS, Coralliaires, t. i. p. 114, (1857).

Corallum fleshy, filled with granular spicula, which do not project from the surface; base enlarged, adherent to foreign bodies; trunk usually destitute of polyps near the base; above, dividing more or less into lobes or branches; polyps completely retractile into cells, which scarcely rise above the surface of the cœnenchyma, and are not armed with prominent spicula; tissue of the trunk and branches membranous, or more or less coriaceous; within, cavernous, with tubes running to each branch.

This genus differs from *Ammothea*, to which it is closely allied, in not having prominent, verruciform cells; from *Nephthya*, in the same character and in the absence of large navicular spicula around the cells; from *Sarcophytum*, in its lobed or arborescent mode of growth.

Alcyonium carneum Agassiz.

Halcyonium carneum Agassiz, Proc. of the American Association, 1850, p. 209. *Alcyonium digitatum* Stimpson, Synopsis of the Marine Invert. of Grand Menan, p. 7, 1853, (in Smithsonian Contributions, Vol. VI.)

Base expanded, adhering to rocks or dead shells; from this arises a more or less cylindrical, thick, naked trunk, which, after a short distance, divides into several large branches, some of which in their turn give off smaller ones, thus producing a much branched, arborescent form; branchlets short, somewhat enlarged, and rounded at the ends when contracted.

The cells are small, crowded on the ends of the branchlets, leaving the trunk and principal branches naked; polyps when expanded much exsert, nearly half an inch, but capable of entire retraction; walls and tentacles near their bases strengthened by slender spicula, arranged obliquely in eight double rows, so as to form V-shaped lines, with the angle towards the ends of the tentacles. The spicula are imbedded in the tissues, and do not project beyond the surface. The tentacles are long, tapering, narrow lanceolate, with slender and rather distant marginal lobes.

Color somewhat variable, but usually delicate flesh color, sometimes tinged with red, and at other times with yellow. The eggs are bright orange, and often visible through the diaphanous walls.

Range, from Cape Cod to Breton Island, N. S. Generally attached to shells or stones in eight to twenty fathoms; sometimes at low-water mark. (Coll. Mus. Comp. Zoöl.)

In form and mode of branching this species resembles *Gorgonia florida* of Müller,[1] but the branchlets have a different appearance; the true affinities of the latter are somewhat uncertain.

Alcyonium rubiforme Dana.

Lobularia rubiformis Ehrenberg, Corall. des roth. Meer. (1834). *Alcyonium rubiforme* Dana, Zoöphytes, (1846).

Low and glomerate, rising from a slightly spreading base; trunk short, dividing into numerous lobes or short branchlets, which are large and rounded at the end, often subglobular, covered by the polyps; surface between the cells even and granulous. Polyps in expansion much exsert; tentacles long, lanceolate, with rather long marginal lobes.

Color brick red, not diaphanous.

Range, Newfoundland Banks (Coll Essex Institute); northern seas of Europe (Ehrenberg); Behring's Straits (Coll. N. Pacific Expl. Exp.).

[1] Zoologia Danica, tab. 137.

Family Cornularinæ Ehrenberg.

Cornularidæ Dana, Zoöphytes. *Cornularinæ* and *Telestinæ* Milne-Edwards, Coralliaires. *Xeniadæ* (*pars*) Gray, Ann. and Mag. of Nat. Hist., 1859, p. 443.

Corallum tubular, membranous or coriaceous, increasing by buds arising either from creeping stolons or from the sides of erect branches. Tentacles with well-developed lobes in a single marginal row on each side.

In this group I have united the creeping genera, which form the sub-family *Cornularinæ* of Milne-Edwards, with the genus *Telesto*, characterized by its lateral buds and arborescent form. That this is in accordance with their natural affinities is evident from the fact that in two species of *Telesto* I have constantly found small creeping stolons, with rising buds as in *Cornularia*, proceeding from the bases of the larger upright branches, and even in the following species this seems to be the case while young, for the upright stalks forming the clumps are connected together by creeping stolons at the base. The genus *Cœlogorgia* Val. also belongs here, instead of among the *Gorgonidæ*, where it has hitherto been placed.

Genus Telesto Lamouroux.

Corallum tubular, arborescent, increasing by lateral buds from upright branches, and sometimes, also, by basal stolons; walls thin, firm, membranous or like parchment, with eight longitudinal sulcations. Polyps wholly retractile, separated at the base from the cavity of the branch by a thin membrane.

This genus differs from *Cornularia* and its allies in its upright growth and arborescent form; from *Cœlogorgia*, to which it is otherwise closely allied, in its thin, parchment-like walls, while in the latter they are thickened, coriaceous, and spiculose.

Telesto fruticulosa Dana.

Telesto fruticulosa Dana, Zoöphytes, p. 632 (1846); Milne-Edwards, Coralliaires, vol. i. p. 112 (1857).

This is a cæspitose, much branched, fastigiate species. Several stalks, connected at the base by creeping stolons, arise close together, giving off from their sides numerous simple tubes and other branchlets, which again subdivide into two, three, or more. The large branches as well as the branchlets or polyp cells are tubular, with their walls nearly smooth externally, but incrusted throughout by a dark colored parasitic sponge, which also extends over and around the base, and often forms a tubular prolongation at the ends of the polyp cells. The exterior surface of the branchlets is marked by eight distinct sulcations. A specimen in the Museum of Comparative Zoölogy consists of about twelve crowded, erect stalks, four inches high, the cells averaging about .25 inch in length, .08 in diameter. Another larger specimen forms a closely branched clump seven inches high and five in diameter. This is attached to the dead axis of *Leptogorgia virgulata*, which it incrusts for several inches, rising above the broken end in the form of a panicle. The tubes are orange-yellow when free from the investing sponge.

Charleston, S. C. (L. Agassiz); Stono Inlet (J. W. Page, U. S. A.).

Sub-order II. GORGONIDÆ.

Gorgoniadæ FLEMING, History of British Animals (1828). *Gorgonidæ* DANA, MILNE-EDWARDS, and most other authors. *Sarcophyta (pars)* GRAY, Ann. and Mag. of Nat. Hist., 1859, p. 443.

This division, of which the characters have been briefly indicated above, embraces several families, of which the following are the principal: *Gorgoninæ* Ehrenberg, *Plexauridæ* Gray, *Primnoaceæ* M.-Edw., *Gorgonellaceæ* Val., *Isidæ* Lamx., *Corallinæ* Dana, *Briaraceæ* M.-Edw. The first three and the last of these are represented on our coast.

Family GORGONINÆ Ehrenberg (restricted).

Gorgoniées (pars) LAMOUROUX, Polypiers Flexibles (1816). *Gorgoninæ (pars)* EHRENBERG, DANA, MILNE-EDWARDS and HAIME, etc. *Gorgonaceæ (pars)* MILNE-EDWARDS, Coralliaires.

The species of this family are usually much branched in a pinnate or furcate manner, and have always a tendency to spread in a plane, forming a flattened or fan-shaped, often reticulated, frond; very rarely they are simple. The cells are arranged on the edges of the branches, either in regular longitudinal series or in irregular bands, leaving on each side a naked median space, often marked by a groove, due to the contraction of the tissues while drying, above the longitudinal ducts, two of which are always much larger than the rest and pass along the middle of each branch, one on each side, while the smaller ones correspond in number to the linear rows of polyps, beneath which they pass. The axis is horn-like, generally slender and flexible, often compressed.

Genus GORGONIA Linn. (restricted).

Eunicea (pars) EHRENBERG (1834). *Gorgonia* MILNE-EDWARDS, Coralliaires (1857).

Corallum much branched, frequently in a plane; branchlets slender, cells in two or more rows on the edges of the branches, leaving a narrow median space, prominent, rising in the form of papillæ above the surface of the cœnenchyma, which is usually thin.

This genus is nearly allied to *Leptogorgia*, and differs chiefly in the prominent cells, which are not capable of being contracted so as to become level with the general surface; while in the latter, though the cells are often a little prominent and verruciform, they seem to admit of complete contraction.

Gorgonia humilis DANA.

Gorgonia humilis DANA, Zoöph. Expl. Exp., p. 663 (1846).

Corallum low, much and irregularly branched and subdivided, sometimes flattened nearly into a plane; smaller branches subpinnate; branchlets slender, short, irregular, usually bent. Cells small, crowded on the edges of the branchlets in two or three rows, moderately and uniformly prominent. Cœnenchyma minutely granular, with well-marked longitudinal grooves. Axis broadly expanded at the base. dark horn-color in the larger branches, yellow and very slender setiform in the branchlets. Color uniform reddish purple, also pure white. The largest specimens in the Museum of Comparative Zoölogy are four or five inches high, the branchlets about .5 of an inch in length.

Charleston, S. C., attached to stones and shells (L. Agassiz).

Genus Leptogorgia Milne-Edwards.

Gorgonia (*pars*) Lam., Lamx., Ehrenb., Dana, etc. *Plexaura* (*pars*) Valenciennes, Comptes-rendus, xli. p. 12 (1855). *Leptogorgia* Milne-Edwards, Coralliaires (1857).

Corallum branching, often dichotomous; branches slender with a central space on each side destitute of cells, often marked by a median groove, by the contraction of the cœnenchyma, which is usually rather thin, above the principal ducts. Cells flat or but little prominent, arranged in several lateral rows on each edge of the branches, often forming two broad bands, separated by a narrow, median, naked space. Axis horn-like, slender, often compressed.

Leptogorgia virgulata Milne-Edwards.

Corallina fruticosa elatior, etc., Catesby, iii. tab. xiii. p. 13 (1750). *Gorgonia ceratophyta (pars)* Pallas, Elench. Zooph., p. 185 (1766) (non Linn. ed. x.). *Gorgonia viminalis* Ellis and Solander, Nat. Hist. Zoöph., p. 82, tab. xii. f. 2, 3 (1786) (non Pallas). *Gorgonia juncea* Bosc, Hist. Nat. des Vers, iii. p. 32, pl. 3, f. 1, 2, 3 (1802) (non Pallas). *Gorgonia virgulata* Lamarck, Anim. sans Vert., ii. p. 495 (1815); Lamouroux, Polyp. Flex., p. 412 (1816). *Gorgonia Olivieri* Lamx., l. c., p. 400 (1816); Bosc, Nouv. Dict., xiii. p. 313, (1817). *Gorgonia virgulata* Dana, Zoöphytes, p. 662 (1846). *Plexaura virgulata* Valenciennes, Comptes-rendus, xli. p. 12 (1855). *Plexaura viminea* Val., l. c., p. 12 (yellow form). *Leptogorgia virgulata* Milne-Edwards, Coralliaires, i. p. 166 (1857). *Leptogorgia viminea* M.-Edw., l. c., p. 165.

Corallum slender, fasciculate; trunk dividing a short distance above the base into two, three, or more principal branches, rising nearly parallel and dividing a short distance above into a few long, slender, virgate branchlets, which originate chiefly from the inner side of the branches and rise at a very acute angle with them; branchlets somewhat compressed or angular, rarely terete, of almost uniform thickness to very near the end, when they taper abruptly to an obtuse point. Cells small, usually oblong, and not at all prominent on the branchlets, but near the base rounded and a little elevated; on the branchlets they are placed in three or more irregular rows along the edges, leaving narrow naked median spaces. Longitudinal grooves not usually apparent except on the larger branches. Cœnenchyma smooth and rather thin. Axis slender, round, horn colored in the large branches, brownish yellow and setiform in the small branchlets. Color exceedingly variable, most frequently either bright lemon yellow or clear reddish purple, but often orange, light yellow, gray, and white, in all cases uniform on the same specimen, although the most diversely colored specimens often occur attached to the same shell or stone.

According to the drawings of Prof. Agassiz, the polyps are, when expanded, small, slender, and but little exserted. The tentacles are broad, rounded, with numerous, crowded, rather shallow, even lobes. The tentacles are strengthened at the base with small spicula, placed obliquely.

Occurs abundantly a few feet below low-water mark along the coast of Georgia and S. Carolina, extending from St. Mary's River, Fla., to Beaufort, N. C.

A small parasitic shell (*Volva uniplicata* Sowb.) often occurs on the branches of this species, and is invariably of the same color as the specimen upon which it lives. The same is true of another species which lives on *Leptogorgia rigida* Verr. from Acapulco, Mex., a species quite as variable in color as the present.

An examination of numerous specimens of this species in the Museum of Comparative Zoölogy has shown me, that, while it is perfectly distinct from the European species with which it was formerly confounded, and equally so from *L. purpurea* M.-Edw. of southern Florida, several nominal species have been founded on mere variations in its form and color, their inconstancy being readily seen when a large number of specimens are at hand.

Leptogorgia tenuis Verrill.

Branches unequally and distantly dichotomous, arranged somewhat in a plane; terminal branchlets very long and slender; round and smooth. Cells numerous, small, scattered, oblong, with the borders flat or slightly prominent. Median grooves scarcely apparent even on the larger branches. Cells on the smaller branches arranged somewhat in two opposite bands, but not very distinctly so. Axis towards the base black, in the smaller branches very slender, yellow, and translucent, even at a distance of eight or ten inches from the extremities. Colors, yellowish brown and purple.

Long Island Sound (Smithsonian Institution).

Of this interesting species there are numerous specimens in the collection of the Smithsonian Institution, attached to rocks, and labelled "Bay of New York." It is closely allied to *L. virgulata* of S. Carolina, but after comparing it with several hundred specimens of the latter in the Museum of Comparative Zoölogy, I have become convinced that they are distinct. In the present species the branches are more slender and elongated and less numerous than in *L. virgulata;* the cells are smaller and less frequently prominent; the median grooves are less distinct, and the axis is more attenuated and diaphanous. The color, though probably variable, is different in all the specimens that I have seen, being generally dull yellowish brown or purplish, instead of pure yellow, orange, or bright purple.

Family Plexauridæ Gray (emended).

Gorgoninæ (*pars*) Ehrenberg, Dana. *Primnoaceæ* (*pars*) Milne-Edwards. *Plexauridæ* and *Muricidæ* Gray, Ann. and Mag. of Nat. Hist., Dec. 1859, p. 442.

Corallum branching, dichotomous or arborescent, with a horn-like axis, often calcareous and stony at the base. Cœnenchyma well developed, traversed by a series of equally developed longitudinal ducts, arranged in a regular circle around the axis. Cells arranged equally on all sides of the branches, leaving no naked lateral spaces.

In this family I have united *Muricea* with *Plexaura* and *Eunicea,* the only important difference consisting in the spiculose cells of the former; but this seems due rather to the thinness of the external membrane covering them in life than to any peculiarity of the tissue itself, for in *Eunicea* the spicula are as well developed and similarly arranged, though covered by a thicker superficial membrane.

Genus Muricea Lamouroux.

Gorgonia (*pars*) Linn., Pallas, Lamarck, and others. *Muricea* Lamouroux, Exposition Méthodique (1821).

Axis horn-like in the branches, often stony and very solid at the base. Cells prominent, more or less conical, covered with large calcareous imbricated spicula, which appear externally when dry.

Muricea elegans Agassiz, MS.

Trunk large, erect, subcylindrical, somewhat compressed transversely, giving off from its sides in a pinnate manner numerous irregular branches, many of which are again irregularly pinnate, others simple or forked; branchlets very numerous, moderately thick, curved, often pendulous, from one to two inches in length. The cells are numerous but not crowded, prominent, compressed-conical, pointed, not appressed, equal in length to about one half the diameter of the branchlets, covered externally with large, imbricated, fusiform spicula, which are granulated over their whole surface. Between the cells there are still larger spicula placed in a longitudinal or oblique position along the branchlets at the surface of the cœnenchyma.

Color of dried specimens brownish orange; axis black, yellow at the ends. Height of the largest specimen, 22 inches; diameter of trunk, .75 of an inch; of branchlets, .17. (Coll. Mus. Comp. Zoöl.)

Charleston, S. C., off the bar (L. Agassiz).

This species is readily distinguished from either of the four species found about the Florida Reefs by its mode of growth, all the latter being dichotomous, as well as by the form and arrangement of the cells. In the last character *M. elongata* Lamx. and *M. laxa* Verr. resemble it most, but the first has smaller, more crowded, and appressed cells, while the last has much longer and more pointed ones.

Family Primnoaceæ Milne-Edwards.

Gorgoninæ (*pars*) Ehrenberg, Dana, etc. *Primnoaceæ* (*pars*) Milne-Edwards, Coralliaires (1857).

Corallum simple or branched, with an axis containing a large portion of carbonate of lime, especially towards the base, where it is stony, but horn-like in the smaller branches. Cells very prominent, covered with imbricated, scale-like spicula; usually movable at the narrowed base. There appear to be no distinct median grooves; the cells are usually placed equally on all sides of the branches, and often arranged in whorls.

Genus Primnoa Lamouroux.

Gorgonia (*pars*) of earlier authors. *Primnoa* Lamx., Polyp. Flex. (1816).

Corallum branched, usually arborescent. Branches covered with irregularly scattered cells, which are bell-shaped, narrow and movable at the base, and protected by large superficial scales.

Primnoa Reseda Verrill.

Gorgonia Reseda Pallas, Elench. Zooph., p. 204 (1766). *Gorgonia lepadifera* Linn., ed. xii. vol. i. p. 1289 (1768); Ellis and Sol., Esper, Lamarck, and others. *Primnoa lepadifera* Lamx., Polyp. Flex., p. 442 (1816); Blainville, Ehrenberg, Dana, Milne-Edwards, Verrill, Notice of Primnoa from St. George's Bank, Proc. Essex Institute (Feb. 1862).

Trunk large, arborescent, branching in a dichotomous manner, often very thick and stony near the base; branchlets round, tapering to slender flexible points. Cells large, campanulate, irregularly scattered. The cells are capable of moving in different directions, but in preserved specimens are generally turned downward. (Coll. Essex Instit.)

St. George's Bank and Bay of Fundy, in deep waters; northern seas of Europe.

Family Briaraceæ Milne-Edwards.

Corallum branched or irregularly lobed, with thickened cœnenchyma and a spiculose or suberous axis. Cells irregularly scattered on all sides; longitudinal ducts numerous, in one or several irregular rows around the axis.

Genus Paragorgia Milne-Edwards.

Alcyonium (*pars*) Linn., Pallas, Lamarck, etc. *Briareum* (*pars*) Blainville (1830) and Dana (1846). *Lobularia* (*pars*) Ehrenberg (1834). *Paragorgia* Milne-Edwards, Coralliaires, i. p. 190 (1857).

Corallum irregularly branched or lobed with stout branches, large polyps, and a thick spongy axis filled with calcareous spicula, which render the axis quite hard in the larger branches; cells a little prominent, clustered upon the branches into groups.

Paragorgia arborea Milne-Edwards.

Alcyonium arboreum Linn., Syst. Nat., ed. x. (1758). *Lobularia arborea* Ehrenberg, Corall. des roth. Meeres, p. 59 (1834). *Briareum arboreum* Dana, Zoöph., p. 644 (1846). *Paragorgia arborea* Milne-Edwards, Coralliaires, i. p. 190 (1857).

Coarsely and irregularly branched in an arborescent form, often of large size. Branches thick, irregular, covered with large tubercular prominences, on which are clustered the cells; these are large, somewhat prominent, and not very numerous.

Color red or brownish yellow.

Bay of Fundy; Northern Europe.

The only American specimen of this species that I have seen was presented by Dr. Wm. Wood to the Portland Society of Natural History. This was obtained in the Bay of Fundy by a fisherman, but nothing definite could be learned concerning the precise locality or depth in which it occurred. Not being able to obtain the specimen for examination, I have prepared the above description from European specimens in the Museum of Comparative Zoölogy.

Genus Titanideum Agassiz, MS.

Corallum irregularly dichotomous or simple; cœnenchyma rather thick, suberous, very spiculose, traversed by well-developed longitudinal ducts arranged in a single series around the axis. Cells disposed on all sides of the branches, not prominent. Axis perfectly distinct from the cœnenchyma, compact, but soft, cork-like, composed of closely united calcareous spicula.

This genus is closely allied to *Briareum*, but differs in having a much more distinct and compact axis, and longitudinal ducts in a single circle, as well as in its mode of growth.

Titanideum suberosum AGASSIZ, MS.

Spongy Keratophyte ELLIS, Nat. Hist. Corallines, p. 63, tab. 26, P. Q. R. (1754). *Gorgonia suberosa* ELLIS and SOLANDER, p. 93 (1786), (*nec* PALLAS *nec* ESPER). *Briareum suberosum* DANA, Zoöph., p. 643 (1846).

The corallum, consisting of one or several stalks, which rise from a thick, broadly spreading and incrusting base, branches in an irregularly dichotomous manner, the branches curving outward at the base, often to a considerable distance, and then rising nearly parallel, forming a somewhat fastigiate clump. Branches long, rigid, subcylindrical, tapering slightly towards the obtuse ends, often crooked, strongly compressed at the axils, from two to eight inches long, and one quarter of an inch in average diameter. Cells oval, perfectly level with the surface, arranged equally on all sides of the branches, nearly in quincunx, about one twelfth of an inch distant. Cœnenchyma firm and thick, with a smooth surface. Axis in alcoholic specimens very distinct, dark fuscous; when dry the axis is somewhat less distinct than before, yellowish brown, and closely adherent to the cœnenchyma.

Color uniform orange or dark red.

Height of the largest specimen examined, 12 inches; diameter of the trunk, .6. This specimen divides, one and a half inches above the base, into three primary branches, and these afterwards into twelve secondary ones, some of which are again furcately divided. (Coll. Mus. Comp. Zoöl.)

Charleston, S. C.; Stono Inlet; Beaufort, N. C.

This singular and very interesting species, first described and very well figured by Ellis in 1754, seems to have been entirely unknown to later naturalists, until rediscovered by Prof. Agassiz at Charleston in 1852. Subsequently it was dredged by Mr. Stimpson at Beaufort, N. C. The former specimens are dull orange, the latter deep red, but in other respects they agree perfectly. The finest and largest specimens were recently obtained by Dr. J. W. Page, U. S. A., at Stono Inlet, and presented by him to the Museum of Comparative Zoölogy.

Sub-order III. PENNATULIDÆ.

The characters of this group have been briefly indicated above (page 3). It corresponds nearly with the genus *Pennatula* of Linné and Pallas, *Polypes flottants* Lamarck, *Pennatulaires* Blainville, *Pennatulina* Ehrenberg, *Pennatulidæ* Fleming, Dana, Milne-Edwards, Herklotz, etc.

This division, if we omit *Umbellularia*, which is imperfectly known, contains four well-marked families, viz: I. PENNATULINÆ Dana (restricted), including *Pennatula, Pteroides, Pteromorpha, Sarcoptilus, Ptilosarcus, Lioptilum*; II. PAVONARINÆ Dana (restricted), embracing *Funiculina, Virgularia, Lygus, Stylatula, Sycialium*; III. VERETILLINÆ Gray (emended), containing *Veretillum, Cavernularia, Sarcobelemnon, Lituaria, Kophobelemnon*; IV. RENILLINÆ Gray (emended), embracing only *Renilla* and an undescribed genus.

Of these families the last is alone represented on our Atlantic coast, so far as known at present; but on the Pacific coast two genera of *Pennatulinæ* have been found, and also two species of *Stylatula*.

Family Renillinæ Gray (emended).

Pennatulinæ (*pars*) Ehrenberg, Dana. *Renilleæ* Gray, Ann. and Mag. of Nat. Hist., v. p. 20 (1860).

Polyps arranged symmetrically on the upper surface of a more or less flattened cavernous disk or frond, to the lower surface of which there is attached a hollow locomotive organ, in the form of a peduncle, destitute of a solid axis.

Genus Renilla Lamarck.

Alcyonium (*pars*) Linn., Syst. Nat., ed. x. (1758). *Pennatula* (*pars*) Pallas (1766); Ellis and Sol. (1786). *Renilla* Lamarck, Hist. des Anim. sans Vert. (1816); Blainville, Ehrenberg, Dana, Milne-Edwards, etc. *Herklotzia* Gray, Ann. and Mag. of Nat. Hist., 1860, vol. v. p. 24.

Frond more or less reniform, with a notch or sinus in the posterior edge; lower surface somewhat striated with radiating lines; upper surface with scattered cells surrounded by spicula, which usually project a little above the surface. Polyps when expanded much exsert, but capable of entire retraction. Among the perfect polyps are scattered numerous rudimentary individuals, which appear like clusters of small white papillæ. The peduncle is attached to the lower surface at or near the sinus; it is hollow, more or less coriaceous, filled, like the surface of the frond, with calcareous spicula, but capable of a great amount of contraction and expansion; a membrane divides it into an anterior and posterior longitudinal chamber. The former communicates with a large cavity occupying the central and posterior portion of the upper surface, and from this by numerous openings with other cavities, filling the whole interior of the frond, and connected with the polyps. The posterior chamber communicates directly with a large cavity at the origin of the peduncle, and then by means of numerous small openings with the other cavities of the disk. The tentacles have rather long lobes, in a single row on each side.

The genus *Herklotzia* of Gray, founded, apparently, on the figure and description of *Renilla Edwardsii* by Herklotz, appears to differ in no respect from *Renilla*, all the characters assigned to it existing in *R. reniformis*, the type of the present genus.

Renilla reniformis Cuvier.

Kidney-shaped Sea-Pen Ellis, Phil. Trans. 1763, p. 427, pl. 19, figs. 6–10. *Pennatula reniformis* Pallas, Elench. Zooph., p. 374 (1766); Ellis and Solander, Hist. Zoöph., p. 65 (1786). *Alcyonium agaricum* Linn., Syst. Nat., ed. xii. p. 1294 (1768). *Renilla americana* Lamarck, Hist. des Anim. sans Vert., t. ii. p. 429, and 2d ed. p. 646 (1816); Blainville, Man. d'Actinologie, p. 518 (1834); Ehrenberg, Corall. des roth. Meeres, p. 65 (1834). *Renilla americana* (*pars*) Dana, Zoöphytes, p. 588 (not the figure, which is *R. Danæ* nob.) (1846). *Renilla reniformis* Cuvier, Règne Animal, 2d ed. iii. p. 319 (1830); Gibbes. Fauna of S. Carolina (App. to Tuomey's Geol. Survey) no description (1846); Agassiz, On the Structure of the Halcyonoid Polypi, p. 10 (Extract from the Proceedings of the Am. Association for 1850) (not *R. reniformis* Herklotz, which is *R. Danæ* nob.). *Renilla americana* Milne-Edwards, Coralliaires, t. i. p. 220 (excluding the synonym, *R. violacea* Q. and G., which is a distinct species).

Frond rounded reniform, or heart-shaped, a little longer than broad; sinus extending about one third across the disk, rounded within, the posterior lobes meeting, or overlapping somewhat, behind; peduncle well developed, bulbous at the end and enlarged where it joins the disk to form, in part, the dorsal central cavity of the disk. Lower surface of the frond nearly smooth, but marked with fine radiating striæ, filled with small spicula, and with a net-work of light-colored lines. Cells few, rather large, surrounded by small and slightly prominent spicula; rudimentary individuals numerous, irregularly scattered among the cells, a little prominent, composed of eight or ten little lobes.

Color of the disk, when living, according to the drawings of Prof. Agassiz, a vivid reddish purple; peduncle the same color, except at the tip and the point of union with the disk, where it is lighter; polyps diaphanous, delicate bluish white, the walls with specks of brown and a circle of brown spots just below the tentacles; tentacles diaphanous with a marginal line of brown on each side, widening towards the base.

The polyps are arranged symmetrically on each side of a narrow naked space, extending from the sinus more than half across the disk, and situated above the large central chamber within; when expanded they are much exsert, but less so than in other species of the genus. The tentacles are narrow lanceolate, with rather distant, long lobes, which are confined principally to the outer half. Mouth oblong, with four small rounded lobes on each side.

This species is capable of distending itself greatly with water, when it becomes very thick and swollen, thinnest at the edges; the peduncle can expand to four or five times its length when contracted. According to Prof. Agassiz, who has carefully studied it while living,[1] it is remarkably phosphorescent, emitting a "golden green light of a most wonderful softness." Its ordinary position when expanded is to have the peduncle buried perpendicularly in the sand and swollen into a bulb at the end. In locomotion the disk itself can be used, either by alternately contracting and expanding the two lateral portions, or by expanding and extending the anterior end and then contracting so as to form a transverse constriction which gradually passes off posteriorly. (Coll. Mus. Comp. Zoöl.)

It is found quite commonly at low-water mark and in pools left by the tide on the coast of Georgia and South Carolina, extending as far northward as Beaufort, N. C.

Order II. ZOANTHARIA.

The structural features which characterize this order are principally the combination of the spheromeres in multiples of six, and the presence of interambulacral spaces between them, in which the new spheromeres are developed during growth, together with the simple tubular structure of the tentacles, which vary in number from twelve to several hundred.

The lateral walls of the spheromeres, forming radiating partitions, of which the principal ones extend from the outer wall to the digestive sac, have been called *lamellæ* by Dana, and *septa* by some later writers; but since the latter term has been definitely applied by Milne-Edwards and Haime to the solid plates formed, in many genera, within the spheromeres, between the *lamellæ*, it ought to be used in this sense alone.

Owing to the great advance made in our knowledge of the structure of this group within a comparatively recent time, through the careful investigations of Dana, Milne-Edwards and Haime, and others, the number of terms that must necessarily be employed in the description of their parts has been greatly increased, but, in order to avoid con-

[1] Proceedings of the American Association, 1850.

fusion, we have endeavored to use in each case that name which was first definitely applied to any part, although in some cases it has been found necessary to restrict the meaning somewhat, as in the instance above mentioned.

The sub-order ACTINARIA of Dana, if we exclude the *Lucernaridæ*, *Cyathophyllidæ*, and *Favositidæ*, which have been shown by Prof. Agassiz to belong to the class of Acalephs, corresponds to the order as here limited. The order ZOANTHARIA of Milne-Edwards, after removing, in the same way, the *Tabulata* and *Rugosa* to the Acalephs, is also equivalent to the present group.

The name ZOANTHARIA (Zoantha) was first applied to this division, with nearly the same limits as at present, by Blainville in 1830.[1]

Milne-Edwards has divided the order into three principal groups or sub-orders.

I. ACTINARIA, corresponding nearly to the family *Actinidæ* Dana.

II. ANTIPATHARIA, equivalent to *Antipathaceæ* Dana.

III. MADREPORARIA, including *Madreporaceæ*, *Caryophyllaceæ*, and part of *Astreaceæ* of Dana.

The first two of these divisions we adopt almost without change, but it seems necessary to divide the *Madreporaria* into three equivalent groups, which shall rank as sub-orders equal in value to the others, as Prof. Agassiz suggested in his lectures several years ago. These groups will stand as follows, viz: I. FUNGARIA, or FUNGIDÆ, embracing the *Fungidæ* of Milne-Edwards, together with *Merulina* and *Echinopora*; II. ASTREARIA, or ASTREIDÆ, including the *Astreidæ* and *Oculinidæ* of Milne-Edwards, and perhaps also *Caryophyllidæ*; III. MADREPORARIA, equivalent to the *Madreporariæ perforatæ* of Milne-Edwards, and including *Madreporidæ*, *Gemmiporidæ*, *Eupsammidæ*, and *Poritidæ* as families.

Of these sub-orders, *Actinaria*, *Antipatharia*, and *Astrearia* are represented on this coast.

Sub-order I. ACTINARIA.

This group as restricted by Milne-Edwards comprises only a small part of the forms included by Dana under the same name, for in the latter case it corresponds nearly to the entire order *Zoantharia*, as now limited; it seems, however, entirely unnecessary to introduce any other name for the present division.

This sub-order is peculiar in having the muscular system highly developed in nearly all parts of the body, but more particularly in the walls, which are therefore more or less soft and contractile throughout their whole extent and never deposit within their substance solid calcareous corals. The basal or abactinal region is also generally muscular and so specialized as to be used in locomotion. The tentacles vary from twelve to many hundred, in the different genera, but are usually numerous. The species are mostly simple, but a few bud from basal expansions or stolons, and others, which are naturally simple, may do so abnormally, like several *Actininæ*.

A large number of groups are embraced in this division, which have been variously considered as families, sub-families, sections, or genera, by different authors; but with the imperfect knowledge existing at the present time in regard to the details of their anatomy, it is scarcely possible to assign true limits or rank to all these various groups, although some of them seem to be well-marked families. For the present the following seems to me the most natural arrangement of the families: MYNIADINÆ; THALASSIANTHINÆ;

[1] Dictionnaire des Sciences Naturelles, Zoophytes.

Actinidæ, including as sub-families *Phyllactinæ*, *Antheadæ*, *Bunodidæ*, *Sagartiadæ*, and *Actininæ* of Gosse; Ilyanthidæ; Cerianthidæ; and Zoanthidæ.

Representatives of all these except the first two are found on our coast.

Family Actinidæ.

Form in expansion more or less cylindrical, rising from a broadly expanded, basal disk, which is usually wider than the column, adherent, muscular, and used in locomotion. The tentacles are simple, numerous, in several rows near the margin.

This group includes several well-marked divisions which appear to have the rank of sub-families, viz: *Actininæ*, in which the body is contractile; the walls either smooth or papillose, apparently imperforate; a row of colored vesicles surrounds the margin at the base of the tentacles, corresponding in position to the eye-specks of other radiates:[1] *Bunodidæ*, having large tentacles; the body rather short, moderately contractile; the walls covered with vertical rows of papillæ, corresponding to each spheromere; the upper vesicle of some of the rows usually larger than the others, and homologous with the colored ones of the preceding group: *Phyllactinæ*, in which the uppermost vesicles are developed into lobed, adhesive, or tentacle-like organs: *Sagartiadæ*, having an elongated, very contractile column, the walls perforated with special openings (*cinclides* Gosse) through which are thrown out thread-like, offensive organs (*acontia*); the exterior frequently covered by adhesive suckers, but not often with prominent papillæ: *Antheadæ*, with long cylindrical tentacles not capable of being contracted within the body, owing to the rudimentary condition of the muscular system of the lamellæ; the walls are without appendages of any kind.

All these sub-families except *Actininæ* are found within our limits, and comprise the majority of the polyps living on this coast.

Sub-family Bunodidæ.

Actinines verruqueuses Milne-Edwards, Coralliaires (1857). Family *Bunodidæ* Gosse, Ann. and Mag. of Nat. Hist., 3d series, i. p. 417 (1858); Actinologia Britannica (1860).

Genus Bunodes Gosse.

Actinia (*pars*) Linnæus, Cuvier, Lamarck, Dana. *Cribrina* (*pars*) Ehrenberg (1834). *Bunodes* Gosse, Trans. Linn. Soc., xxi. p. 274 (1855); Observations on Actiniadæ, Ann. and Mag. of Nat. Hist., 2d series, xvi. p. 294 (1855). *Cereus* (*pars*) Milne-Edwards, Coralliaires (1857) (*non* Oken).

Column elongated, subcylindrical in expansion, hemispherical in contraction; walls firm, with numerous prominent papillæ arranged in vertical lines corresponding to the chambers within, the uppermost, marginal ones larger than the rest, generally distended, and diaphanous, the others capable of adhering strongly to foreign bodies. Tentacles well developed, large, subcylindrical, not very numerous, perforated at the tips. Lamellæ (in *B. cavernata*) broad throughout their whole length, nearly uniformly thickened with

[1] *Actinia primula* Drayton (Dana, Zoöphytes) pl. 2, f. 12–15, belongs to this division, and appears also to have *acontia*.

longitudinal and oblique muscular fibres; at some distance from their upper ends there are rather large, circular, peripheric pores.

This genus corresponds in part to *Cereus* of Milne-Edwards, but that genus, as established by Oken in 1815, had for its type the *Actinia bellis* of authors, which belongs to the genus *Sagartia* of Gosse. The genus *Cribrina* of Ehrenberg covers very nearly the same ground as *Cereus* of Oken, and has for its principal character the perforation of the walls, which is essentially a character of the *Sagartiadæ*, and not of this division.

Bunodes stella Verrill.

Actinia coriacea? Stimpson, Marine Invert. of Grand Menan, p. 7 (1853).

Plate I. figures 1–8.

When in full expansion the column is generally cylindrical, or pillar-shaped with the middle portion smallest, enlarging more rapidly towards the disk than the base; the height is often double the diameter of the column, but sometimes does not exceed it. In contraction it becomes a depressed cone, covered with radiating lines of suckers. The tentacles are large, not very numerous, about equal in length to the diameter of the disk, often somewhat exceeding it; in ordinary expansion they are largest near the base, tapering gradually to the obtuse tips. The largest specimens observed have seventy-two tentacles of which twenty-four belong to the fifth cycle, which is incomplete. Specimens of about an inch in diameter have usually forty-eight tentacles, forming four complete cycles. Those of the first two cycles are somewhat larger than the rest, forming the inner row of twelve, which are generally held in an upright position during expansion, while the rest are curved more or less outward and downward and sometimes curiously curled and bent in all directions. The column is sulcated with vertical lines corresponding to the radiating partitions within, while the ambulacral spaces, corresponding to the chambers below each tentacle, are slightly swollen, and have, at intervals of about one fourth of an inch, rounded suckers or verrucæ, the upper one of each vertical row being more prominent than the rest, and situated at the margin of the disk, just below the base of the tentacle; lower down the verrucæ belonging to the ambulacra of different cycles do not correspond horizontally, so that they appear to be arranged nearly in quincunx. These suckers have the power of adhering firmly to pieces of shells, grains of sand, etc. Specimens when found are generally covered by such foreign substances, which, however, they very soon discard when confined in an aquarium. The disk is flat or somewhat convex at the centre; mouth usually a little prominent, with four conspicuous folds; it often has the form of a cross, the transverse opening longest; at each end there is a small, rounded lobe with a larger one on each side projecting inward and often meeting, thus enclosing a crescent or heart-shaped space at each angle; the sides of the mouth are formed by a broad lobe on each side, which is often again divided into secondary ones.

The color of the column is generally pale, pellucid olive-green, sometimes flesh-color; tentacles, disk, and verrucæ a lighter tint of the same, each tentacle sometimes having a well-defined ring of opaque white near the middle and, at the base on the inside, a conspicuous spot of the same, which is broad below and often cordate, diminishing upwards and blending into the general hue, but these spots are absent on those of the first two cycles; from the mouth six conspicuous flake-white bands radiate to the primary tentacles;

the two that are in a line with the mouth being the broadest; occasionally the other four are indistinct or wanting; sometimes these are fainter, while radii extend to those of the second cycle; inside of the mouth light orange.

The largest specimens that I have observed were about two inches high in full expansion, and one and a fourth across the disk, with the tentacles about the same in length. A specimen, half an inch across the disk, had forty-eight tentacles; another, one quarter inch in diameter, had thirty-six tentacles, and the colors of the adults; one, only one tenth of an inch, had some tentacles of the third cycle developed, with the star on the disk represented by six white spots, two of them largest. The young, when excluded, have usually twelve tentacles, and average about one twelfth of an inch in diameter. (Col. Mus. Comp. Zoöl.)

Cape Elizabeth, Me., in pools near low-water mark, buried to the tentacles in sand; Eastport, Me., and Grand Menan, N. B., in crevices of rocks near low-water mark.

This beautiful species resembles *B. gemmacea* of Europe in many respects, and may well be considered the American representative of that species. A comparison that I have had an opportunity of making at the Museum of Comparative Zoölogy between living specimens of *B. gemmacea*, sent from the Free Public Museum of Liverpool through Captain J. Anderson, and *B. stella*, obtained at Cape Elizabeth, Me., by Mr. E. S. Morse, has enabled me to ascertain the specific characters of the two species.

In *B. gemmacea* the tentacles are more numerous, and smaller in proportion to the size of the body; the verrucæ are more numerous and crowded, and the marginal ones are less prominent; the colors are in vertical bands on the column, and the tentacles are variegated, while in *B. stella*, at least in all the specimens yet observed, the color of the column and tentacles is uniform light greenish, or flesh-color, sometimes with white bands, or basal spots, on the latter. The six white lines radiating from the mouth across the disk seem, also, to be a constant and characteristic feature of *B. stella*, since they could be traced in almost every specimen that I have observed,— even in young ones not more than one fourth of an inch in diameter.

Its favorite situation appears to be in the fissures and crevices of ledges and rocks, overgrown by fuci and other sea-weeds, in the lower portion of the littoral zone. In such places it is often found in great profusion lying in a flaccid, half-expanded state while the tide is out. It thrives well in confinement, and makes a very elegant appearance when expanded. It appears to be most active during the night, but will frequently remain in full expansion during the whole day.

Bunodes cavernata Verrill.

Actinia cavernata Bosc, Histoire Nat. des Vers (1802); 2d ed. vol. ii. p. 260, pl. 12, f. 2 (1830, apparently the young). *Actinie cavernate* Bosc, Nouveau Dictionnaire d'Histoire Naturelle, i. p. 163, pl. A. 4 (1816, same figure as the preceding). *Actinia cavernata* Gibbes, Fauna of South Carolina, p. xxiii., no description (Appendix to Tuomey's Geol. Survey, 1846). *Actinia cavernosa* McCrady, Proc. Elliott Society of Charleston, S. C., i. p. 275 (1858).

The column is short, cylindrical in expansion, capable of contracting into a hemispherical form, densely covered with prominent, persistent papillæ, arranged near together in vertical series, well developed even at the base, the upper, marginal ones somewhat larger and lighter colored. Tentacles numerous, subequal, the longest less than the radius of the disk, (about one half an inch long in large specimens,) crowded in numerous indistinct rows near the margin, rather thick, tapering from near the base to the acute points. Mouth capable of eversion, rather long, narrow, provided with several lateral folds.

Color of the body dull yellowish, or greenish brown, with numerous small dark brown spots, arranged somewhat in vertical lines, occasionally forming irregular streaks; tentacles yellowish green, with a dark brown spot at the base, and often with longitudinal lines of brown or dark green, and tipped with white; disk dark, greenish brown, lightest around the mouth.

Height of a good-sized specimen in expansion, 2 inches; breadth, 1.5.

Charleston, S. C. (L. Agassiz).

There are numerous good specimens of this species in the Museum of Comparative Zoölogy, and in the possession of Prof. Agassiz are several colored drawings made from life by Mr. Burkhardt, from which I have taken the description of the tentacles and colors.

Prof. Agassiz has also another drawing representing a cluster attached within the cavities of a stone, apparently the young of this species. These are nearly uniform greenish, with the tentacles tipped with white, thus corresponding very well with the description by Bosc.

Genus Rhodactinia Agassiz.

Cribrina (*pars*) Ehrenberg (1834). *Rhodactinia* Agassiz, Comptes-rendus, xxv. p. 677, Nov. 1847 (extract from a letter to Humboldt); Revue Zoologique par la Société Cuviérienne, 1847, p. 394 (another extract from the same letter as the preceding). *Bunodes* (*pars*) Gosse, Trans. Linn. Soc. xxi. p. 274 (1855). *Cereus* (*pars*) Milne-Edwards, Coralliaires (1857). *Tealia* Gosse, Ann. and Mag. of Nat. Hist., 3d ser. i. p. 417 (Jan. 1858).

Column low, shorter than broad; the walls firm and thick, with a thickened fold near the upper margin in adult specimens; surface covered by distant verrucæ, which are arranged in vertical rows along the ambulacral regions, but so remotely as to appear scattered; these are less prominent and persistent than in the preceding genus, being often so reduced as to be scarcely apparent. Mouth large, often everted; tentacles large, cylindrical, with distinct openings at the ends.

This genus, named and briefly described by Prof. Agassiz in 1847, corresponds perfectly to that recently established by Gosse under the name *Tealia*, the typical species of the former, *R. Davisii*, being the American representative of *R. crassicornis* of Europe, which is the type of *Tealia*.

Rhodactinia Davisii Agassiz.

Rhodactinia Davisii Agassiz, Comptes-rendus, xxv. p. 677 (Nov. 1847); Revue Zoologique Soc. Cuviérienne, p. 394 (1847, the deep-water form). *Actinia obtruncata* Stimpson, Marine Invertebrata of Grand Menan, p. 7 (1853, the littoral form). *Actinia carneola* Stimpson, l. c. p. 7 (young).

Plate 1. figure 9.

The column is short, cylindrical, broader than high, sometimes four inches broad and about two high in expansion; walls thick, somewhat cartilaginous, with scattered papillæ, which are usually but slightly prominent, and often inconspicuous, the surface then appearing smooth or reticulated; these, though widely scattered, are in vertical lines, corresponding to the sub-tentacular chambers within; in adult specimens there is a thickened fold near the upper edge of the column. Tentacles numerous, in several indistinct rows near the margin of the disk, conical or cylindrical, thick, rather short, obtusely rounded at the ends, or even at times club-shaped. The disk is usually flat, but sometimes convex. The mouth (actinostome) is large, oblong, with a similar fold at each end, in front of which on both sides there is a large rounded fold, giving a somewhat rectangular appearance to the mouth in some states of expansion. The stomach is often everted so as to completely disguise and replace both the mouth and disk.

The color is often bright cherry red with the tentacles paler and diaphanous, but is quite variable according to the locality. The specimens from deep water are generally as described above, or flesh-color and diaphanous. In shallower water (8 to 15 f.) they are frequently blotched or streaked with bright red on a light red or greenish ground color; the tentacles are pale flesh-color, each with a band of pink near the middle and another near the tip, with often a white band between, and white at the extreme tip; the disk pink with radiating lines of red, which embrace the bases of the tentacles and sometimes fade away before reaching the mouth, which is surrounded by an ill-defined circle of red, the angles of the mouth pale orange. Littoral specimens are most commonly of a clear, bluish green color, irregularly blotched with crimson or reddish brown; tentacles pellucid, or light red, with a diffuse spot of white on the inner side of the base and an undefined white band near the middle; the disk greenish with purple radii. The following are descriptions made from life of some of the other colors frequently met with at Eastport, Me.: 1. Column deep crimson; tentacles light reddish brown, each with a broad band of dark crimson near the end, bordered below by a faint light band, the extreme tip whitish; disk light greenish brown with radiating lines of purple; mouth surrounded by a broad, faint ring of purple (littoral). 2. Column flesh-color with blotches of orange red; disk flesh-color with bright red radii which do not reach the mouth; the latter light orange (littoral). 3. Column flesh-colored, mottled with bright pink with a band of pink just below the tentacles; radii of the disk bright pink, well defined; tentacles, each with a large white spot at the base on the inside and a smaller one on the outside, a broad pink band above the base, a narrow whitish band in the middle, then another broad pink band, and, finally, white at the tip (in 20 f. rocky bottom). 4. Column uniform light pink with an orange tinge, except a band of a somewhat lighter tint below the tentacles, the surface appearing smooth; tentacles pink with lighter tips; disk very pale pink with well-marked spots of opaque white in front of the bases of the tentacles (20 f. shelly bottom). The last form seems perfectly identical with Stimpson's *Actinia carneola.* Some of the smaller specimens agree with his description in every respect, but do not appear to differ in anything except color from the young belonging to the ordinary varieties.

This species discharges young of various sizes, and probably eggs also. Some of the young, about .98 of an inch in diameter, had but six tentacles, which were longer than the width of the disk; others, about .10 of an inch, had twelve tentacles, six of them much longer than the diameter of the disk; another about twice as large had twelve tentacles well developed, and two very small ones appearing regularly in one of the systems and two others appearing in one half of another system; others, about a quarter of an inch in diameter, had twenty-four tentacles about equal in length to the diameter of the disk and some very small ones appearing in some of the systems. Specimens an inch in diameter when expanded have about sixty tentacles, which are nearly half an inch long, the primary ones being placed about midway between the mouth and the margin. (Coll. Mus. Comp. Zoöl.)

Range from Nantucket shoals to Grand Menan, perhaps to Labrador, and in depth from the middle region of the littoral zone to thirty fathoms.

On the shore it seems to prefer ledges covered thickly with fuci, and in such places is often very abundant, completely covering the cavities and fissures. It is often associated with *Bunodes stella,* but does not confine itself so exclusively to fissures as the latter, and is very seldom, if ever, found coated by foreign substances. In form it is very mutable, both ends being capable of great distension or contraction either separately or at the same time. It will often assume a variety of the most diversified forms within a very few minutes.

This species is very near *R. crassicornis* of Europe, having been considered the same by some naturalists, and like it has a wide range of variation in color and form, but it seems never to have the surface, even in littoral specimens, strongly and persistently papillose, like that of the latter. The tentacles, also, appear to be uniformly blunter at the ends than in the corresponding European forms.

The genera *Bolocera* and *Stomphia* of Gosse seem to me to be founded on forms of *R. crassicornis*, and in the present species corresponding forms occur. A large specimen, which I obtained off Grand Menan in 35 fathoms, agrees with the genus *Bolocera* in all respects, having the same character of surface and furrowed tentacles, which were not withdrawn even after the rough treatment received during its capture; yet I am unable to separate it from *R. Davisii.* Another specimen dredged in 12 fathoms, rocky bottom, at Eastport, Me., had the characters of *Stomphia.*

This individual had the tentacles in two marginal rows, a convex disk with a broad, oblong mouth, having a large fold at each end and fourteen radii on one side and fifteen on the other. The walls were apparently smooth. The color of the column was pale pink mottled with vermillion, with a colorless band just beneath the tentacles; disk light scarlet with a colorless circle near the mouth, the margin of which was bright red; tentacles transparent, bluish white, with a scarlet band near the middle and another close to the end. This specimen, when expanded, was about an inch and a half in diameter and the same in height; in contraction, low and nearly flat.

Sub-family Phyllactinæ Milne-Edwards.

The characters of this group have been indicated above, page 15.

Genus Aulactinia Agassiz, MS.

In this genus the base is adherent, but capable of distension; column elongated, moderately contractile, and capable of involving the tentacles and disk with its summit, but not of contracting into a low cone; upper part covered with prominent, adherent verrucæ or suckers arranged in vertical rows, the uppermost one in each row situated just below the tentacles, larger than the others, trilobed, the lobes again subdivided on their lower sides; wall near the margin thickened into a fold. Tentacles numerous, subequal, well developed. Mouth (actinostome) with a fold at each angle, one of which is considerably the largest. Internal lamellæ well developed, much narrowed near the base, thickened above with strong longitudinal muscles, which serve to contract the disk and tentacles. The walls are thin, leathery, or parchment-like, and but slightly muscular; digestive sac short and thick; ovaries attached to the upper part of the lamellæ.

Aulactinia capitata Agassiz, MS.

Column very long, cylindrical, or more commonly clavate, diminishing from the enlarged summit to a constriction near the base, below which it suddenly expands to the edge of the basal disk, which is narrower than the upper part of the column; the base is thin and often distended. Walls thin, parchment-like, the upper half covered by large, prominent, adhesive verrucæ, concave at their summits, arranged rather closely in vertical rows, becoming obsolete below. The rows are separated by wider naked spaces; margin with a thickened fold, below which there is a circle of large compound verrucæ, which are the uppermost ones in the vertical rows of suckers; these are short, thick, distinctly trilobed on the lower side, each lobe again divided below into short rounded tubercles or crenulations. Tentacles very numerous, short, thick, pointed, arranged in many rows; the twelve inner ones, belonging to the first two cycles, are thicker than the rest, six of them generally curved inwards in expansion, and six erect; the outer ones are more slender, scarcely shorter, and are generally carried spreading outward; mouth with two opposite crescent-shaped folds.

Color brownish gray or greenish brown, with lighter longitudinal lines; disk similar to the column, with darker radiating lines, and a lighter space around the mouth; tentacles yellowish green, with a dark brown median line on the inner side, interrupted by several white spots, which often blend into a white line near the base; verrucæ gray.

Height in expansion often 6 inches; greatest diameter 1.35; length of tentacles about .30. (Coll. Mus. Comp. Zoöl.)

Charleston, S. C., buried to the tentacles in sand (L. Agassiz); Fort Macon, N. C. (Sam'l Cabot); Beaufort, N. C. (A. S. Bickmore).

Sub-family Sagartidæ.

Family *Sagartidæ* Gosse, Actinologia Britannica, p. 9 (1860).

This division has been established by Gosse on the character of having openings like loopholes (*cinclidæ*) piercing the walls, through which peculiar thread-like organs, consisting in great part of lasso-cells, are thrown out for defence when irritated, and possibly, in some cases, for the purpose of obtaining food. These thread-like organs are often, also, thrown out from the mouth and accidental ruptures of the walls in great numbers. When protruded for self-defence, they are slowly withdrawn again, if the exciting cause be removed. This I have observed in *Metridium marginatum*, and Gosse mentions the same fact in respect to other species. The mode in which the threads are expelled and withdrawn seems to be entirely mechanical, depending upon the flow of water through the cinclidæ, the force of the current impelling the flexible filaments either outward or inward according to its course.

There are a few additional characters which separate this group from other *Actinidæ*, though mostly of a negative nature, and at the same time it is somewhat doubtful whether *cinclidæ* and *acontia* are not present in other divisions, namely, *Actininiæ*, *Anthcidæ*, and, possibly, *Bunodidæ*.

Genus Metridium Oken.

Actinia (*pars*) Linnæus, Pennant, Ellis and Solander, Lamarck, Cuvier, etc. *Metridium* Oken, Lehrbuch der Naturgeschichte, iii. p. 349 (1815). *Actinotoba* (*pars*) Blainville, Dict. des Sci. Nat. and Manuel d'Actinologie, p. 322 (1830–34). *Cribrina* (*pars*) Ehrenberg, Corall. des rothen Meeres (1834). *Sagartia* (*pars*) Gosse, Manual Mar. Zoöl. *Actinoloba* Gosse, Actinologia Britannica, p. 11 (1860).

Column very contractile and changeable in form, often much elongated, but capable of contracting into a broad, flattened cone. Walls smooth, destitute of suckers, pierced with scattered cinclidæ, thickened near the summit into a fold surrounding the column, above this thinner and diaphanous. Disk broad, deeply folded or frilled at the margin. Tentacles very numerous, the inner ones largest, scattered on the disk, the outer ones becoming gradually very small and much crowded, fringe-like at the margin. Acontia very abundant, but not emitted except after considerable irritation. The mouth has a broad and deep groove at one angle and twelve to sixteen folds along each side.

This genus as established by Oken had for its type *Actinia dianthus* of authors, the European representative of *M. marginata*. By Ehrenberg and several other writers the name has been applied to *Actinidæ* of entirely different characters, belonging to the *Phyllactinæ*, thus excluding the typical species. We follow Milne-Edwards in retaining the name for this genus, with *M. dianthus* as its type.

Metridium marginatum Milne-Edwards.

Actinia marginata LeSueur, Journal Acad. Nat. Sciences Philad., vol. i. pt. i. p. 172 (1817). Gould, Report on Invertebrata of Massachusetts, p. 349 (1841). Agassiz, Twelve Lectures on Comp. Embryology, p. 38, pl. xx. xxxii. xxxiii. (1849). *Actinia marginata* and *Actinia dianthus?* Stimpson, Synopsis of Marine Invert. of Grand Menan, p. 7 (1853). *Actinia marginata* Leidy, Journal Acad. Nat. Sciences Philad., 2d series, vol. iii. p. 140 (1855). *Metridium marginatum* Milne-Edwards, Hist. Nat. des Coralliaires, vol. i. p. 254 (1857). *Actinia dianthus* Dawson, On Sea-Anemones and Hydroid Polyps from the Gulf of St. Lawrence, Canadian Naturalist and Geologist, vol. iii. p. 402, figs. 1 and 2 (1858). *Actinia marginata* Mrs. L. Agassiz, A First Lesson in Natural History, p. 10, figs. 1 to 6 (1859). *Actinia marginata* Agassiz, Contributions to the Natural History of the United States, vol. iii. p. 39, fig. 8 (1860).

The form of this species is very changeable; in contraction it is hemispherical or a broad low cone, sometimes almost disk-like; in expansion most commonly like a thick cylinder or pillar, higher than broad, with an expanded base, the summit surmounted by the broad, elegantly frilled or undulated disk, with the tentacles drooping in a graceful fringe on all sides and concealing the upper part of the column. Sometimes it becomes greatly elongated and attenuated, the disk looking somewhat like a flower supported on its peduncle. This form is most frequently assumed by young specimens. Column smooth, more or less cylindrical, thickened near the top into a slightly elevated band or fold, which is about an inch below the base of the tentacles in large specimens; above this it becomes thinner and diaphanous. Acontia emitted copiously from scattered cinclidæ and from the mouth when strongly irritated. They often extend to the distance of two inches or more. Disk much broader than the column, its margin usually thrown into about twelve deep undulating folds or frills, which are, however, quite changeable in size and number in the same individual. Tentacles arranged on the outer half of the disk, leaving a central area free from them; the inner ones are scattered distantly and somewhat irregularly and are larger than the rest, sometimes half an inch in length; they decrease rapidly in size towards the margin, where they become very crowded and quite small, looking like a delicate fringe along the edge.

Color exceedingly variable, but most commonly with the column some shade of brown; the disk and column about the fold a light shade of the same, or flesh-colored; the tentacles grayish, often with lighter tips; mouth similar in color to the column, but lighter. There are, however, so many styles of coloration that it may be well to mention a few, though to characterize all the variations would be scarcely possible. The following are often met with: —

1. Salmon-colored throughout; tentacles a lighter tint of the same.

2. Yellowish brown, streaked with lighter near the base; tentacles delicate flesh-colored; mouth like the column.

3. Umber brown, with plain, dark slate-colored tentacles.
4. Umber brown; tentacles light slate, having a ring of white near their bases.
5. Umber, with white tentacles.
6. Yellowish umber; tentacles a lighter tint of the same.
7. Column irregularly blotched and mottled with brown on a whitish ground color; tentacles light grayish brown.
8. White or very light flesh-colored throughout.
9. Yellowish red or brick-red, with flesh-colored tentacles.

Very young specimens are slender in expansion, with long slender tentacles, which are not crowded. The disk is not undulated, and there is no apparent fold on the column. Their color is uniform yellowish white or flesh-color. Specimens of about half an inch in diameter show indications of the characteristic fold or thickening of the wall, but have the disk scarcely undulated. Their tentacles are long and slender, considerably crowded, and often marked by a longitudinal dark line. They are frequently lengthened to a very great extent when expanded.

The larger specimens commonly met with are about 4 inches high in ordinary expansion; 3 broad across the disk; 1.50 at the centre of the column; inner tentacles .50 in length; outer .10 to .20. Specimens of much larger size are occasionally found.

Range, from Buzzard's Bay, Long Island Sound, and near New York, to Gaspé, Canada East. (Coll. Mus. Comp. Zoöl.)

This species is very closely allied to *M. dianthus* of Europe and by some writers has been considered the same. A careful examination of living specimens of the latter in the Museum of Comparative Zoölogy, forwarded from the Free Public Museum of Liverpool, through the kindness of Capt. J. Anderson, and a direct comparison with others of *M. marginata*, has convinced me, that, though very similar in appearance, they are perfectly distinct. In *M. dianthus* the inner tentacles are more scattered over the disk, leaving a more limited central area free from them than in our species, in which they consequently appear more concentrated towards the margin of the disk. The tentacles are also smaller in the former and more delicate than in individuals of the same size of the latter. The margin of the disk in the specimens examined of *M. dianthus* appeared more numerously and deeply frilled than in any specimens that I have seen of *M. marginata*. The margin of the mouth of the latter is nearly always of the same color as the column, but of a lighter tint; while in the former it is said by Gosse to be "generally rufous or orange red, whatever the hue of the body."

This opinion has been much strengthened by the testimony of Dr. Wm. Stimpson, who has had unrivalled opportunities for the study of the marine invertebrata, both on this coast and on that of Great Britain, for I have been assured by him that he has found the difference in the arrangement of the inner tentacles constant among hundreds of specimens of both species, which he has examined. He therefore considers them sufficiently distinct.

The Fringed Actinia is the most abundant species along the whole coast of New England and the Provinces of New Brunswick and Nova Scotia. It ranges in depth from low-water mark to thirty fathoms, and is often, also, found attached to the sides of fissures and in rocky pools between tides, particularly in places sheltered from the sun. Not unfrequently it is seen attached in large numbers to the piles of wharves at or just below low-water mark; but its favorite haunts are rocky situations or bottoms covered by stones of moderate size. In the Bay of Fundy it is particularly abundant and grows to a very large size. At Mount Desert, on the coast of Maine, I have seen, during a very low tide, a rocky bottom completely covered for acres with this species, from low-water mark to a depth of two fathoms or more, and so thickly crowded on every exposed surface of rock that from a stone no more than six inches in diameter I have taken upwards of sixty individuals of various sizes. On the southern coast of Labrador we failed to detect this species during numerous careful searches at low-water mark and while dredging in favorable situations. It is not improbable, however, that it may yet be found there, as well as on the coast of Newfoundland. This species, like *M. dianthus*, often separates from the border of its base small fragments, which in a few days become perfect individuals. This is analogous to basal budding, so often seen in other families of polyps.

Genus Cereus Oken.

Actinia (*pars*) Ellis and other early authors. *Cereus* Oken, Lehrb. der Nat. (1815, type *Actinia bellis* Ellis and Sol.). *Actinocerus* Blainville, Dict. Sci. Nat. (1830); Man. d'Actinologie, (1834). *Cribrina* (*pars*) Ehrenberg, Corall. roth. Meeres (1834). *Sagartia* (*pars*) Gosse, Trans. Linn. Soc., xxi. p. 267 (1855). *Cereus* (*pars*) and *Adamsia* (*pars*) Milne-Edwards, Coralliaires (1857). *Sagartia* (*Scyphyia*) Gosse, Actinologia Brit., p. 123 (1860).

Column very contractile, pillar-like in expansion, capable of great elongation. Walls extending to the margin, uninterrupted by a fold or thickening, pierced by numerous cinclidæ, the upper part provided with numerous, well-developed suckers. Acontia emitted freely. Tentacles very numerous, the inner ones somewhat scattered on the disk, the outer crowded at the margin. Disk broad, scarcely frilled, though often undulate.

In adopting the genus *Cereus* of Oken I find it necessary to change materially the limits assigned to it by Milne-Edwards, and to take as the type of the group *Actinia bellis* Ellis and Sol., which is the first species named by Oken, and the one which, more than any of the others, possesses the characters mentioned by him, particularly the perforation of the walls. This character does not appear to exist among those species included in section A of the genus as defined by Milne-Edwards, which corresponds to *Bunodes* and *Rhodactinia.* The group as here restricted embraces a part of the genus *Sagartia* of Gosse, but I am disposed to consider those species of the latter genus claimed by him as most typical, worthy of being separated generically under that name. The genus *Cribrina* of Ehrenberg appears to be perfectly synonymous with *Cereus* as defined by Oken, although the first species named under it has not the character of perforated walls assigned by him to the genus.

Cereus sol Agassiz, MS.

Actinia sol Agassiz, MS. 1849.

The column is very changeable in form, in expansion often like a moderately elongated pillar, enlarging both towards the base and summit. It is capable of contracting into a globular form or into a low, flattened cone; walls provided for a short distance below the tentacles with well-marked suckers, towards the base nearly smooth. Acontia emitted to the distance of two inches from scattered openings, apparently not very numerous. Base adherent to shells, etc., somewhat expanded, circular, the tissue diaphanous, beautifully marked by the internal radiating lamellæ. Tentacles numerous, amounting to several hundreds in large specimens, arranged in many indistinct circles; inner ones largest, placed about midway between the mouth and the border of the disk, about one-half an inch in diameter, regularly scattered; outer ones much smaller, very crowded; mouth often prominent at the summit of the protruded disk, oblong, provided with seven lobes or folds on each side, with the largest lobe at the posterior end.

Colors of the column arranged in eight broad, longitudinal stripes of cinnamon-brown, alternating with somewhat narrower ones of gray, the whole surface irregularly sprinkled with small dark brown spots, darkest just below the tentacles; mouth bright yellow, surrounded by a ring of purple or crimson, outside of which the disk is bluish gray, often with alternately lighter and darker radiating lines; inner tentacles flesh-colored, with a dark spot at the base, four or five dark brown spots or bands on the upper half, and a longitudinal line of white on each side; outside of these are others similarly colored but with less distinct dark markings, having bright red tips; the next are orange-yellow with red tips but without distinct dark spots; while the outer ones are nearly white, sometimes with yellow bases and a small spot of red at the tips. According to the drawings of Prof. Agassiz a large specimen about 3 inches high and 1.75 in diameter has the tentacles colored as follows: 72 inner banded tentacles, of which 24 are larger and without red tips; 144 orange-colored with red tips; 288 outer ones, which are in great part white, making a total of 504. (Coll. Mus. Comp. Zoöl.)

Near Charleston, S. C., living on shells inhabited by hermit-crabs (L. Agassiz).

This species is more brilliant in its colors than any other known American species, and when fully expanded the blending of the hues of the variegated tentacles around the brightly colored central area produces a very beautiful effect. From the observations of Prof. Agassiz it appears to be a very active species, contracting powerfully on irritation.

A specimen from alcohol on dissection has the lamellæ broad at the upper portion and thickened with strong muscular fibres; towards the base they are narrowed, leaving a large central cavity, but the principal ones suddenly expand again below, so as to meet at the centre of the base. The ovaries are in clusters low down on the lamellæ; the acontia attached to their upper part, not very numerous. The peripheric pores of the lamellæ are well developed, and near their upper edges. The walls are very muscular, both transversely and longitudinally.

A form at first thought to be a distinct species, and originally named *A. guttata* Ag. MS., but afterwards supposed by Prof. Agassiz to be the young of this species, was also observed and drawn at Charleston in 1849. The column is light reddish brown with vertical rows of brownish orange spots, and a lighter band just below the tentacles. The disk is light brown, with a yellow ring around the mouth and a flake-white line crossing it in a line with the longest diameter of the mouth and running up on the bases of two opposite inner tentacles. The inner tentacles are greenish yellow; the outer ones yellow with white lines. Two specimens were observed about half an inch high when expanded, the largest one with about 200 tentacles.

Sub-family Antheidæ.

Actininæ (pars) Milne-Edwards, Coralliaires. Family *Antheadæ* Gosse, Actinologia Britannica.

This group is distinguished principally by its elongated, non-contractile tentacles, and the absence of suckers, verrucæ, and other appendages upon the walls. The genus *Aip-*

tasia, referred here by Gosse, is said to have acontia, but these organs appear to be wanting in the other more typical genera.

Genus Dysactis Milne-Edwards

Column often cylindrical, changeable in form, but not capable of involving the tentacles and disk. Tentacles of two kinds: the inner series long and slender; the outer short, conical, and subequal.

Dysactis pallida Agassiz, MS.

Actinia pallida Agassiz, MS. (1849).

Column sometimes slender and elongated, more frequently short subcylindrical with a narrow base, enlarging above the middle to the margin of the broad disk; walls longitudinally sulcated; disk broad and flat. Mouth elongated, narrow; in alcoholic specimens with prominent margins divided into about twelve small lobes on each side, leaving a fold at each angle. Tentacles well developed; the twelve inner ones often more than an inch long, very slender and flexible; outer ones numerous, very short, conical; between these two sets there are some intermediate in size, about half an inch in length.

Color of the column light brownish yellow, obscurely striated with lighter; disk similar in color, sometimes with a lighter halo around the mouth; longest tentacles a lighter tint of the same, usually with white spots on the inner side, and a larger one at the base; sometimes there are alternate darker spots.

The largest specimens were 1.25 inches in height; .50 in diameter at the middle; .75 across the disk. (Coll. Mus. Comp. Zoöl.)

Charleston, S. C. (L. Agassiz).

One of the drawings belonging to Prof. Agassiz represents an individual with slender filaments, perhaps acontia, protruding from the mouth. I have not been able, however, to demonstrate the existence of these organs from alcoholic specimens.

Family Ilyanthidæ.

Actinines pivotantes Milne-Edwards, Coralliaires (1857). *Ilyanthidæ* (*pars*) Gosse, Actinologia Britannica (1860).

Column elongated, tapering below to a pointed or rounded base, without a distinct disk. Base continuous with the walls, often capable of inflation and extension so as to serve for locomotion, and also, sometimes, of adhering to foreign bodies. Tentacles usually in limited numbers, well developed. Acontia apparently wanting.

Genus Ilyanthus Forbes.

Isachmæa (*pars*) Ehrenberg, Corall. des roth. Meeres (1834). *Iluanthos* Forbes, British Actiniadæ, Ann. and Mag. of Nat. Hist., vol. v. p. 181 (1840); Milne-Edwards. *Ilyanthus* Johnston, Gosse.

Column elongated, obconical, tapering below nearly to a point; surface smooth, destitute of suckers and verrucæ. Base very small, scarcely distinct, perforated (in our species) by a central opening. Tentacles marginal, in three or more cycles.

The species of this genus appear to live buried to the tentacles in mud or sand. The terminal pore has not been observed in all of them.

Ilyanthus chloropsis Agassiz, MS.

Actinia chloropsis Agassiz, MS. (1849).

Body when fully expanded elongated and rather slender, tapering to the base, capable of involving the tentacles and contracting into a short obovate form. Base narrow with a rather large terminal pore. Walls thin, smooth, firm in texture. Tentacles short, pointed, numerous, arranged in several rows; mouth long and narrow; disk flat.

Color of column light bluish green, somewhat diaphanous, with lighter longitudinal striations; tentacles light yellowish green with a white spot at base and a white line on each side; disk yellowish green; mouth bright yellow.

Length, in expansion, 3.50 inches; breadth, .75; when contracted in alcohol, length, 1.25; breadth, 1.00.

Charleston, S. C. (L. Agassiz).

This species appears to be very rare. The only specimen known is in the collection of the Museum of Comparative Zoölogy.

Ilyanthus lævis Verrill.

The form of this species when partly contracted in alcohol is elongated, obconical, tapering below to an obtuse point. Column smooth, marked by faint longitudinal lines corresponding to the internal lamellæ. Tentacles, thirty-six, placed about one tenth of an inch within the margin of the disk, and arranged in two imperfectly defined rows; they are slender, moderately long, acute at the ends. The summit of the column forms, outside of the tentacles, a thin marginal expansion, having its edge crenulated with small rounded teeth. The base does not appear to have a terminal opening. Length of the column, 1 inch; greatest diameter, .25; length of tentacles, .15. Color unknown.

Eastport, Me. (L. Agassiz).

The only specimen that I have seen is preserved in alcohol in the Museum; therefore, the description of this interesting species must remain, for the present, very imperfect. It differs from *I. scoticus* Forbes, specimens of which, collected at Oban, Scotland, by Dr. Stimpson, are also in the Museum of Comparative Zoölogy, in its more slender and elongated form and shorter tentacles, as also in having a broad margin of the disk outside of the tentacles. In the last character it agrees with *I. Mitchellii* Gosse.

Genus Edwardsia Quatrefages.

Edwardsia Quatrefages, Mém. sur les Edwardsies, Ann. Sci. nat., ser. 2, xviii. p. 65 (1842).
Scolanthus Gosse, Ann. and Mag. of Nat. Hist., 2d ser. xii. p. 157 (1853).

Column very slender, elongated, the upper and basal portions thin and membranous, the middle region covered by a thick epidermal secretion, forming a tube into which the membranous portions may be contracted. Base capable of being distended, and when in that state of adhering slightly by its surface to rocks, etc.; at other times tapering to a point. Tentacles slender, marginal, in three or four cycles, the third sometimes incomplete.

Edwardsia sipunculoides Stimpson, MS.

Actinia sipunculoides Stimpson, Marine Inv. of Grand Menan, p. 7, pl. 1, fig. 2 (1853).

Plate I. figures 12, 13.

Column very slender, elongated, cylindrical, the central portion traversed by eight longitudinal sulcations, between which it is somewhat swollen in the form of broad, rounded, slightly prominent ribs, crossed in contraction by numerous strong transverse wrinkles. The inferior naked portion when expanded is about one half an inch in length, pointed at the extremity, without any distinct basal disk, but capable of being greatly distended, and in this condition of adhering to stones by its membranous surface. This region is marked with eight white lines, which meet at the central point of the base and are continuous with the eight sulcations of the column. These coincide with the corresponding internal partitions, which are seen through the transparent walls. The upper naked portion, in expansion, is one third of an inch or more in length, smooth and cylindrical. The tentacles are about thirty-six in number, arranged somewhat crowdedly in two rows close to the margin. They are long, slender, tapering to a point, the outer ones a little shorter than the inner, which are twice longer than the diameter of the disk; mouth with four small but prominent lobes on each side.

The color of the central, sheathed portion is usually yellowish brown, but varies to black, according to the situation and the color of the mud where found; basal naked area, pellucid yellowish white; upper naked portion, yellowish, surrounded, about midway between the tentacles and sheath, by a ring consisting of eight lunate, arrow-shaped, or square opaque white spots, which are close together and sometimes extend downward at their lower angles, forming a white line along the sides of each invection; sometimes there is a trace of another ring of smaller white spots lower down; tentacles transparent yellowish white, sprinkled with numerous flake-white dots, sometimes with small white spots at the outer base. Mouth and "stomach" bright red, the former generally prominent; disk yellowish, with faint white radii, and white spots often surrounding the base of the tentacles.

Length of the largest specimens when in full expansion, about 5 inches; in diameter, .15; when contracted, about 1.5 inches in length. (Coll. Mus. Comp. Zoöl.)

Eastport, Me., and Grand Menan, N. B., in gravelly mud under stones at low water.

This interesting species has, as yet, been found in very few places, and, with one exception, very sparingly in its localities. In the vicinity of Eastport, Me., at a point just south of Dog Island, I succeeded in obtaining several hundred specimens in a very short time by turning over the large stones, when they were seen projecting from the mud, chiefly near the edges of the stones, looking much like some species of worms. As many as fifteen or twenty were sometimes found under a single stone. This locality was first discovered by Dr. Stimpson. They here occupy the lower third of the littoral zone. Some force is usually required to pull them from their burrows, but this seems to be owing to the distension of their bases rather than to any adhesive power. When put into sea-water they expand readily and move about with worm-like gyrations. When touched, they suddenly jerk away the upper part of the body before withdrawing the tentacles. They feed readily, like most *Actinidæ*, upon bits of clams and other mollusks.

Edwardsia sulcata Verrill.

The column is long, smooth, with twelve strong sulcations; the intermediate spaces swollen into prominent ribs, which are crossed by slight, transverse wrinkles; upper part in contraction thickest, tapering below. Naked basal portion distended, rounded, with a small, concave, smooth area at the end, the sides marked with twelve lines which do not meet in a point, but disappear on the small terminal convex area, which, however, is scarcely distinct from the sides. Tentacles not observed.

Color light yellowish brown. Length in contraction, 1.25 inches; diameter, .30.

Chelsea Beach, Mass., thrown up after a storm.

Never having seen this species except when contracted in alcohol, I am able to give but a very imperfect description. It differs widely from the other species in the character of the column. From *E. sipunculoides* it may readily be distinguished by its larger size and less slender form, by its much smoother surface and lighter color, and by the twelve sulcations instead of eight.

For a fine specimen of this species, and the first that I had seen, I am indebted to Mr. A. S. Packard, Jr., who found it in the spring of 1862; but Dr. Stimpson informs me that he has also obtained the same species at Chelsea.

Genus Halcampa Gosse.

Actinia (*pars*) Peach, in Johnston's British Zoöphytes. *Peachia* (*pars*) Gosse, Trans. Linn. Soc., xxi. p. 271 (1855). *Halcampa* Gosse, Ann. and Mag. of Nat. Hist., 3d series, i. p. 418 (1858).

Column very contractile, much elongated and slender in expansion, occupying holes in the earth or among rocks; in contraction irregularly cylindrical, often with constrictions; walls membranous throughout, diaphanous, the upper portion provided with well-developed suckers. Base capable of being enlarged and greatly distended, without a distinct disk, but capable of adhering slightly by its surface to foreign bodies, apparently imperforate. Tentacles short, in two or three cycles, the last usually imperfect in some of the systems, whole number not known to exceed twenty. The internal lamellæ are very thin next the wall, but near the middle have a very strong, longitudinal, muscular thickening, which narrows both above and below. Ovaries very large, extending about half way to the base. The peripheral pores of the lamellæ are large and well defined.

Halcampa albida Agassiz, MS.

Corynactis albida Agassiz, Proceedings of the Boston Society of Natural History, vol. vii. p. 24 (1859).

Body very changeable in form, sometimes very long, slender, and attenuated; at other times short cylindrical or clavate; not unfrequently forming two distinct portions separated by a constriction in the middle, the parts above and below being of the same size, or the upper one may be distended while the lower is contracted and slender; in extreme contraction short, oval, rounded at both ends, but the basal end smallest. The base may be expanded into a thin, transparent, bladder-like form, or by contraction become pointed. Surface of the column smooth below, diaphanous, marked faintly by the longitudinal and transverse muscular fibres, and deeply by twenty sulcations corresponding to the internal lamellæ; upper portion covered by prominent suckers arranged in a vertical row along each ambulacral space, each one situated in the centre of a little square. Tentacles twenty, slender, with rounded knobs at the ends. They are arranged in three cycles forming six systems, but in two of the systems next to one end of the anterio-posterior axis, the tentacles of the third system are wanting. Those of the first and second cycles in the perfect systems are nearly equal, and about double the length of those of the third cycle; in the imperfect systems those of the second cycle correspond in length to those of the third in other systems.

Color of the column light brownish yellow; tentacles lighter, the knobs at the tips dark brown.

Average length in expansion, about 3 inches; thickness, .40; length of tentacles, .25. (Coll. Mus. Comp. Zoöl.)

Long Island Sound, shores of Nantucket, Martha's Vineyard, and Cape Cod, buried to the tentacles in sand near low-water mark.

This species is closely allied to the following, and like it is remarkable for its great size compared with the European representatives of the genus. From *H. producta* it differs in having larger and less numerous suckers, which extend lower down on the column, and in the knobbed character of the tentacles. It appears to be quite common in its localities. According to the observations of Dr. Stimpson and Mr. B. T. Morrison, it occupies in expansion the whole length of its burrows, which are sometimes a foot deep, and can contract and withdraw itself to the lower end when disturbed. In some instances the base was found to be adherent to a small pebble at the bottom of the hole.

Halcampa producta Stimpson, MS.

Actinia producta Stimpson, Some Remarkable Marine Invertebrata inhabiting the shores of South Carolina, Proceedings of the Boston Society of Natural History, v. p. 110 (1856).

Plate I. figures 10, 11.

Column in expansion very long, somewhat claviform above, slender below, in contraction cylindrical, often constricted. Base capable of distension, and of adhering to pebbles or shells beneath the surface of the sand or mud in which it burrows. The surface of the body is marked by twenty longitudinal sulcations, corresponding with the internal lamellæ and continuing to the centre of the base; the upper portion, for about a third of the whole length, is covered by numerous prominent suckers arranged closely in rows along the ambulacral spaces, the upper ones largest, decreasing downward until they become obsolete near the middle. "Tentacles twenty, short, stout, enlarged and rounded at the ends, which are covered with white dots. Five of these tentacles usually stand erect, the remaining ones curving over and alternating by threes with the erect ones. The animal retracts its tentacles very slowly when disturbed."

Color of the column transparent yellowish green. Length in contraction about 3 inches, diameter, .75; in expansion probably 8 or 10 inches, since the base was found attached at that distance below the surface.

Near Fort Johnson, S. C. Found in considerable numbers buried in the mud on the flats near low-water mark. Its position is indicated, after the tide has retired, by little cracks on the surface of the mud, which radiate from a small central hole.

This interesting species, the largest described of the genus, is known to me only through the description of Dr. Stimpson and the drawings which he has generously placed at my disposal.

Genus Bicidium Agassiz.

Bicidium Agassiz, Proceedings of the Boston Society of Natural History, vii. p. 24 (1859). (?) *Philomedusa* Müller, Arch. fürg Natur. xxvi. p. 57 (1860).

Body elongated, turbinate, or obconic, tapering to the base. Column sulcate, surface without apparent suckers or cinclidæ, uniform along its whole extent. Tentacles twelve, in two cycles, short, thick, marginal. Mouth large, enclosed at one end by a prominent extension of the disk, forming a large conchula, which is partially divided into tentacle-like lobes at the summit; the other end surrounded by small lobes corresponding in number to the tentacles. Base with a terminal pore.

This genus is very closely allied to *Peachia* Gosse, but has a still more remarkable structure surrounding the mouth. It also lacks suckers, and has the tentacular system less developed.

Bicidium parasiticum Agassiz.

Bicidium parasiticum Agassiz, Proceedings of the Boston Society of Natural History, vii. p. 24 (1859).

Plate I. figures 14, 15.

Form usually turbinate, tapering below to an obtusely rounded base; in contraction sometimes ovate, largest in the middle, broader than long, each end involved. Surface strongly furrowed by twelve sulcations corresponding to the internal lamellæ, between the grooves much swollen and corrugated by transverse wrinkles, no suckers apparent. Tentacles twelve, short, thick, swollen in the middle, obtuse at the tips. Conchula or proboscis greatly developed, surrounding one end and about one half the length of the mouth, and when expanded about as long as the tentacles; its summit is divided into three principal lobes, one opposite the angle of the mouth and one on either side of this, and two subordinate ones, which are about opposite the centre of the mouth. The remaining margin of the mouth is divided into prominent lobes, decreasing in size as they approach the angle opposite the conchula.

Color light purplish brown with a bluish iridescence, similar to that of *Cyanea arctica.*

Length in expansion, 1.25 inches; greatest diameter, .4. (Coll. Mus. Comp. Zoöl.)

Nahant, Mass., to Eastport, Me., parasitic on the large red jelly-fish, *Cyanea arctica,* often imbedded in the tissues of the lower surface of the disk.

Family Cerianthidæ.

Cerianthidæ Milne-Edwards and Haime, Distribution méthodique (1852); Milne-Edwards, Coralliaires, i. p. 306 (1857). *Ilyanthidæ* (*pars*) Gosse, Ann. and Mag. of Nat. Hist., 3d ser. i. p. 417 (1855); Actin. Brit. (1857).

Form elongated, tapering to the rounded or pointed base, which is destitute of a disk. Tentacles not retractile, greatly developed, numerous, arranged in two series, one marginal and the other immediately surrounding the mouth, a tentacle in both sets arising from each spheromere. Internal lamellæ unequal; one pair extending to the base or nearly so, the others shorter, leaving a wide central cavity.

This very peculiar group was first established by Milne-Edwards and Haime in 1852, but with somewhat different limits from those now given. *Ilyanthus* was then included with the typical forms, but has been separated more recently by Milne-Edwards. Gosse has again united the two groups under the name *Ilyanthidæ.* The two families appear, however, to be sufficiently distinct.

For the present I prefer to include the genus *Arachnactis* in this division, although possessing peculiarities which might possibly warrant the establishment of a distinct family for it, as has been suggested by Mr. A. Agassiz.[1] But it seems quite doubtful to me whether its adult condition has been hitherto observed, while the young of *Cerianthus,* according to the observations of Haime, are free, swimming polyps. The structure and arrangement of the internal lamellæ and the two circles of tentacles are also similar. The peculiarity of the development of the tentacles of *Arachnactis,* so well described by Mr. Agassiz, seems also to have an intimate relation to the singular arrangement of the internal lamellæ of *Cerianthus.* It is also probable that the development of the tentacles in the latter follows the same law as in the former.

Genus Cerianthus Delle Chiaje.

Moscata (?) Rénier, Eléments de Zoologie, partie 3, fasc. i. (1828). *Cerianthus* Delle Chiaje, Descr. anim. inv. della Sicilia citeriore, iv. p. 124 (1841); Milne-Edwards and Haime, Distr. méthodique(1852); J. Haime, Mémoire sur le Cérianthe (Ann. des Sci. nat., 4^{me} ser. i. p. 341, 1854); Milne-Edwards, Coralliaires (1857).

Column long, cylindrical, highly muscular and contractile, but not capable of involving the disk; form variable, but usually enlarged towards the disk, tapering slightly below to the pointed or sometimes swollen base; walls firm and strong, smooth externally, naturally enclosed in a loosely investing and unattached tube composed principally of cast-off lasso-cells, or nematocysts, forming a felt-like substance of considerable tenacity. Base with a subterminal opening, serving for the expulsion and introduction of water. Tentacles in both sets long, slender, very numerous, not contractile. Internal lamellæ very unequal, one pair extending to the base, the others shorter and narrower, those opposite the first pair smallest. The species, so far as observed, are hermaphrodite.

Cerianthus americanus Agassiz, MS.

Cerianthus Agassiz, Proceedings of the Boston Society of Natural History, vii. p. 24 (1859).

Column very long, cylindrical, expanded at the top, tapering gradually below; in expansion, often two feet or more long; in contraction, six or eight inches. Body enclosed in a loosely investing tube, buried in the mud. Tentacles long and numerous, the outer series (125 or more) are from 1.25 to 1.50 inches long, slender, very flexile, usually much curled at the ends; inner series similar, about .75 long, nearly the same as the former in appear-

1 Journal of the Boston Society of Natural History, vol. vii. p. 529 (1863).

ance; often brought together and spirally twisted in a central bundle. Base with a small but distinct opening.

Color of column dark cinnamon-brown, lined longitudinally with a lighter tint of the same; outer tentacles cinnamon-brown, lighter at the bases; inner series darker, marked with white longitudinal lines; disk bright yellow, the central portion brown; at the bases of the tentacles spotted with dark brown.

Length of the largest specimen in expansion, 24 to 28 inches; diameter at disk, 1.50; at centre of body, 1 inch. (Coll. Mus. Comp. Zoöl.)

Charleston, S. C., buried to the tentacles in mud at low water (H. J. Clark, Wm. Stimpson, L. Agassiz); Beaufort, N. Carolina (Wm. Stimpson).

The description of this very interesting species has been drawn chiefly from a beautiful series of drawings in the possession of Prof. Agassiz, made from life by Mr. Burkhardt. It is remarkable for its great size and fine colors.

Genus Arachnactis Sars.

Arachnactis Sars, Fauna Littoralis Norvegiæ, i. (1846). *Arachnactis* Gosse, Actinologia Britannica, p. 263 (1860).

Column of moderate length, elliptical or subcylindrical, rounded at the base, apparently destitute of a terminal opening; surface smooth, in the British species said to be capable of adhering. Tentacles few in number, not contractile, the marginal ones long and slender; those of the inner circle short and thick, corresponding in number with the others. The development of new tentacles in each circle takes place in pairs at one extremity of the anterio-posterior diameter in a bilateral manner. The species swim freely in the sea with the tentacles downward.

Arachnactis brachiolata A. Agassiz.

Arachnactis brachiolata A. Agassiz, Proceedings of the Boston Society of Natural History, ix. p. 159 (1862); Journal of the Boston Society of Natural History, vii. p. 525 (1863).

Body strongly compressed in the plane of the anterio-posterior diameter, rounded at the base, and in all the individuals observed somewhat enlarged. The outer tentacles exceed the column in length; the inner are, in the specimens described, very short, conical, generally carried erect.

Color of body pale ochreous, diaphanous; the lamellæ appearing through the walls like darker lines.

Massachusetts Bay, swimming by night near the surface; very abundant about the first of September (A. Agassiz).

This species has as yet been observed only in the young state. It was then about an eighth of an inch in length, and had sixteen tentacles. It still retained some of the yolk mass at the base, and moved chiefly by ciliæ covering the surface, swimming in an oblique position, the largest tentacles hanging downwards.

For a more detailed account of this interesting form I would refer to the original papers by Mr. Agassiz.

Family Zoanthidæ.

Zoanthes Blainville, Dict. Hist. Nat. (1830). *Zoanthina* Ehrenberg, Corall. des roth. Meer. (1834). *Zoanthidæ* Dana, Zoöphytes (1846). *Zoanthinæ* Milne-Edwards, Coralliaires (1857).

Polyps aggregated, permanently fixed upon rocks, shells, etc. The new polyps arise by budding from basal expansions of the walls in the form either of stolons or broad sheets. Column cylindrical, the summit capable of involution. Tentacles short, conical, placed close to the margin of the disk.

Genus Zoanthus Cuvier.

Actinia (*pars*) Ellis (1767); Ellis and Sol. (1786). *Hydra* (*pars*) Gmelin, Linn., Syst. Nat., ed. xiii. *Zoanthus* Cuvier, Tab. Élém. (1797); Règne Anim. (1817). *Zoantha* Lamarck, Système des Anim. sans Vert., p. 363 (1801); Hist. Anim. sans Vert. (1815); Lamouroux; Dana. *Zoanthus* Ehrenberg, Milne-Edwards.

Base incrusting rocks, shells, or other foreign bodies, sometimes in the form of thin spreading sheets or bands, at other times as narrow creeping stolons. Polyps arising from the spreading base, elongated, subcylindrical, or pillar-like. The surface of the walls is either smooth and covered with mucus, or protected by a layer of sand closely agglutinated to the surface. Disk generally concave, capable of involution, but the polyps contract very little in length.

Zoanthus parasiticus Stimpson, MS.

This species, which is parasitic on shells, has an incrusting base, smooth and uniform on the lower side of the shell, but giving rise to from fifteen to twenty polyps on the upper side, which diverge in all directions. Polyps variable in height and size, those of the upper central portion generally half an inch in height and one eighth in diameter, while those around the margin of the base are not more than half so large, and much crowded. Base spreading over and completely investing dead shells of *Natica*, *Buccinum*, etc., both externally and internally. The substance of the shell in every case has been entirely removed, but the form in all parts is perfectly preserved by the membranes of the polyps, while the cavity is inhabited by a species of hermit crab (*Eupagurus pubescens*). Column pillar-like, smallest in the middle, increasing gradually below, but enlarging rapidly at the summit. Walls thin, covered by a layer of closely adhering, fine sand. When contracted, the summit is slightly concave, and in the medium-sized polyps has seventeen, in the largest twenty-four sulcations, radiating from the centre, which is seldom completely closed. Tentacles forty-eight or more, short, conical.

Off the coast of New Jersey, lat. 40° N., long. 73° W., in 32 fathoms (Capt. Gedney, Coll. Smith. Ins.).

This is the only species of the family yet found on our coast north of Florida. In habits it resembles *Z. Couchii* of England, and, like the latter, will probably be found to assume various forms according to the object upon which it grows. It is a larger species, and the polyps are much less slender in form, with more numerous tentacles. It is also, apparently, nearly allied to *Z. arcticus* Sars, from Northern Europe.[1]

The above description has been prepared from alcoholic specimens in the Museum of Comparative Zoölogy, received through the Smithsonian Institution. By a singular coincidence, the same manuscript name was independently given to this species in 1861 both by Dr. Stimpson and myself.

Doubtful Species.

The following species of *Actinidæ*, which I have never seen, will require further examination before they can be referred to their proper genera.

Actinia rapiformis LeSueur.

Journal of the Academy of Natural Sciences, Philadelphia, i. p. 171 (1817).

"Tentacula short, cylindric, equal, disposed in four rows; body fleshy, very contractile, assuming different forms, and frequently those of a turnip and a pear, the former of which it also resembles in its dull opaque white color; when contracted it is of a subglobular form. The young are more transparent than the old, and are sometimes of a darker color.

"This species dwells in the sands of the coasts of the United States, and raises its head above the common surface for the purpose of displaying its tentacula; when contracted in its habitation, it is concealed below the surface. The individual described was an inch and a half in diameter and four or five inches in length. Discovered at Egg Harbor, on the coast of New Jersey. It is necessary to observe that this *Actinia* is frequently disturbed in its habitation by the waves of the ocean, and is found washed on the sands; in this event, a common observer would take it for a rotten pear, or something similar."

Actinia neglecta Leidy.

Journal of the Academy of Natural Sciences, Philadelphia, 2d series, iii. p. 141 (1855).

"Body, when closed, obpyriform or shortly cylindrical; when expanded, cylindrical, about an inch in length by one fourth of an inch in breadth, smooth, translucent olive-green. Mouth elliptical, with the lip composed of six greenish-white lobes. Tentacles numerous, up to one half an inch in length, brighter olive-green than the body. A single specimen was found in the mud of a sound in the vicinity of Atlantic City, N. J." This is, probably, an *Ilyanthus*.

Anthea flavidula McCrady.

Proceedings of the Elliott Society of Charleston, S. C., vol. i. p. 280 (1858). No description.

This is, possibly, the same as *Dysactis pallida* nob., but since it is merely mentioned by name, there is no possibility of ascertaining its true place.

[1] Aftryk af Vidensk. Forhandlinger i Christiania, 1860.

Actinia (?) nitida Dawson.

Canadian Naturalist and Geologist, vol. iii. p. 404, fig. 3–5 (1858).

This name was provisionally applied to an Actinian which I have not seen. It closely resembles specimens of *Rhodactinia Davisii* of the form named *Actinia carneola* by Dr. Stimpson, and may well prove to be only a variation of that polymorphous species.

"Body short, cylindrical, smooth; color red, arranged in stripes; tentacles triserial, short, conical, striated, reddish; disk prominent, dull purple, with two rows of white spots. Oral bands numerous, flesh-color."

The largest specimens were an inch in diameter and had one hundred and fifty tentacles.

Gaspé, Canada East, 8 to 10 f. gravelly bottom (J. W. Dawson).

Sub-order II. Antipatharia.

In this division the polyps are united, as in the *Gorgonidæ* among the *Alcyonaria*, by a cœnenchyma which connects them laterally; and from the common basal membrane there is in like manner secreted a solid axis (*sclerobase*), which serves as a support. The sclerobase is, however, rarely or never striated, and has a smooth or echinulated surface. The polyps, so far as known, have six simple tentacles, similar to those of many *Actinaria.*

Genus Antipathes Pallas.

Corallum branched; branches but imperfectly coalescent, or not at all so. Axis black, hard, and opaque, with the surface more or less echinulate.

Antipathes Boscii Lamx.

Antipathes Boscii Lamouroux, Polyp. Flex., p. 375, pl. 14, f. 5 (1816); Dana, Zoöphytes, p. 584 (1846); Milne-Edwards, Coralliaires, i. p. 318 (1857).

Corallum finely and densely branched from very near the base, forming an irregular, subflabelliform, matted frond. Branches slender, numerously divided in an irregularly dichotomous or subpinnate manner, frequently coalescent, especially near the base, the reticulations very irregular. Branchlets slender, setiform, the terminal ones from one fourth of an inch to an inch in length. Surface of the branches and branchlets thickly covered by small acute spines projecting nearly at right angles; between the spines minutely scabrous. Color black, the branchlets translucent, dark amber-colored. Cœnenchyma not observed. Height, 10 inches; breadth, 14. (Coll. Mus. Comp. Zoöl.)

Near Charleston, S. C. (L. Agassiz).

Antipathes alopecuroides Ellis and Sol.

Antipathes alopecuroides Ellis and Solander, p. 102 (1786); Dana, Zoöphytes, p. 584; Milne-Edwards, Coralliaires, i. p. 317

Having had no opportunity of observing this species, I quote the original description of Ellis.

"This branched Antipathes has its young branches, which are full of spires and small prickles, disposed in close panicles. The trunk rises from a broad-spread base, and divides immediately into several large branches of one third of an inch diameter; as these rise up, one side of them appears flat, with a groove or channel along the middle part of it, where there are the remains of many little branches that have grown in rows on each side of it. It then divides into branches, and often into other branches, all of which are in form of close panicles, not unlike the fox-tail grass. These panicles are composed of very rough, thorny, minute branches, which are twice as long on one side of the stem as on the other. The outside of this Antipathes is of a grayish color; the inside is black and very brittle. It is near two feet high.

"This was brought from South Carolina, and presented to Corbyn Morris, Esq., F. R. S., and has not before been described."

Sub-order III. Astræaria.

In this division the polyps have elongated, more or less cylindrical tentacles, the surfaces of which are generally covered by distinct papillæ or spots, caused by groups of lasso-cells. The walls are highly developed and likewise the septal organs, and solid corals are formed by the secretion of lime in these parts. The corals have mostly solid, imperforate walls; septa in multiples of six, often in great numbers, compact, imperforate, usually extending on the outside of the walls as costæ. Between the septa transverse plates, one above the other, are formed by basal secretions, or the space is filled from below by a continuous deposit of solid matter, as in *Oculina*.

The last character would exclude the *Turbinolidæ* of Milne-Edwards, which, in most other respects, agree with the *Eusmilinæ*, and ought, perhaps, to be considered as low and simple forms of Astræaria. There is a gradual and almost complete transition from the *Turbinolidæ* through such forms as *Ceratotrochus duodecim-costatus*, in which imperfect transverse dissepiments are often present, to *Parasmilia*, *Cœlosmilia*, etc., among the *Astræidæ*, in which the dissepiments are but slightly developed. There is also a very close connection of the *Turbinolidæ* (*Caryophyllinæ*) through *Paracyathus*, which sometimes has rudimentary dissepiments, with the *Astrangiaceæ* M.-Edw., particularly with such genera as *Phyllangia* M.-Edw. and H. and *Syndepas* Lyman, which have very imperfect dissepiments and, at the same time, nearly entire septa. The polyps, also, seem to have a very close resemblance, since so accurate an observer as Dana united species of *Flabellum* with his genus *Euphyllia*, principally with regard to this feature.

The character among *Turbinolidæ* of always remaining simple has no weight, since there are, also, many simple *Astreidæ*, and especially since the observations of Mrs. Thyme, if accurate, prove that *Caryophyllia* undergoes, while young, complete and extensive fissiparity.[1]

We unite *Oculinidæ*[2] with the *Astræidæ* without hesitation. While young, *Oculina diffusa* and *O. arbuscula* are low, incrusting corals, spreading over the surface of rocks in precisely the same manner as *Astrangia*, and budding in the same way, so that it is even difficult, sometimes, to distinguish the two genera while young. The polyps of these two genera and also of *Cladocora* are very similar in all respects, as is beautifully shown in an excellent series of unpublished plates in the possession of Prof. Agassiz.

[1] On the increase of *Caryophyllia Smithii*, with notes by P. H. Gosse, Ann. and Mag. of Nat. Hist., iii. p. 449 (1859).

[2] This position of *Oculinidæ* was suggested by Prof. Agassiz three years ago, and has been constantly confirmed by further examinations.

Leaving *Turbinolidæ* out of consideration for the present, the ASTRÆARIA may be arranged as follows: —

A. FISSIPAROUS ASTRÆARIA, embracing three families.

I. *Eusmilinæ* M.-Edw. and H., having the edges of the septa entire, without paliform lobes; polyps with the disk in expansion raised above the coral; tentacles well developed, cylindro-conical.

II. *Lithophyllinæ*, corresponding to a part of *Lithophylliaceæ* M.-Edw. These have the edges of the septa divided into strong teeth or spines, without paliform lobes; disk level with the top of the cells; tentacles surmounting the top of the septa, short, conical, numerous (*Mussa, Isophyllia*, etc.).

III. *Mæandrinæ*, including part of *Lithophylliaceæ* M.-Edw., viz.: *Mæandrina, Manicina, Hydnophora, Tridacophyllia, Colpophyllia*, etc., together with *Faviaceæ*. In these the septa have their edges finely toothed or crenulate, with a paliform lobe towards the base. The small tentacles are placed at the top of this paliform lobe, and the disk extends across the cells even with the top of the paliform lobes, and does not rise level with the summit of the walls.[1]

B. GEMMIPAROUS ASTRÆARIA, containing four families.

IV. *Stylininæ*, corresponding with *Stylinaceæ* M.-Edw. and Haime. Septa with entire edges; dissepiments well developed; cœnenchyma absent.

V. *Astræinæ*, embracing only a part of the same group as limited by Milne-Edwards and Haime, viz: *Astræaceæ* (*pars*), *Cladocoraceæ, Astrangiaceæ*. These have dentate septa, rudimentary cœnenchyma, dissepiments usually well developed.

VI. *Stylophorinæ* M.-Edw. and H., including *Stylophora, Madracis*, etc. In these there is a well-developed cœnenchyma, uniting the polyps, which is most compact at the surface. The cells have a tendency to fill up at the surface and remain more open below. Septa mostly entire.

VII. *Oculinidæ*, corresponding to the same group of Milne-Edwards and Haime, with the addition of *Distichopora* and, perhaps, *Errina*. The cells have a tendency to fill up completely from below by deposition of solid matter; dissepiments not very well marked; cœnenchyma well developed, compact.

Of these only the fifth and last are represented within our limits, so far as now known; yet species of all the others, except *Stylininæ*, occur about the Florida Reefs.

Family ASTRÆINÆ Milne-Edwards.

We have restricted this name, as indicated above, to but a small part of the forms included by Milne-Edwards and Haime. This has been done principally from a consideration of the structure of the soft parts. In this respect this group differs widely from most other *Astræidæ*, agreeing more nearly with *Oculina* than with any other division that I have had an opportunity to examine. The upper portion of the polyp has the power of rising out

[1] This peculiar character, which separates *Mæandrinæ* from *Lithophyllinæ*, I have ascertained from numerous examinations and dissections at the Museum of Comparative Zoölogy of alcoholic specimens of *Mæandrina, Manicina*, and *Favia*, compared with *Isophyllia dipsacea*, also in alcohol, and with the figures of the living polyps of *Mussa* and *Symphyllia* in Dana's Zoöphytes. The polyps of *Mæandrina* have also been well figured by LeSueur, Dana, and others.

of and above the cells in all the genera examined, and, on contraction, of sinking back into them. The tentacles are slender and well developed.

This group embraces three divisions of Milne-Edwards, which may be regarded as sub-families, viz: I. *Astræaceæ,* including those genera that form massive corals by the intimate union of the individuals. These bud near or within the disk or from the membrane connecting contiguous polyps ; II. *Cladocoraceæ,* comprising those that bud laterally and in which the polyps are united only at the base, forming branching or cæspitose clumps; III. *Astrangiaceæ,* in which the polyps bud from the base, from basal expansions or, more rarely, from the sides, forming, mostly, low incrusting corals. These last two groups ought perhaps to be united, since the separation between even the typical genera, *Cladocora* and *Astrangia,* is not very clear, the former, while young, budding from basal, creeping stolons, and some species of the latter rising when old into incipient branches and increasing thus by lateral, or even marginal, buds.

The last of these subdivisions is the only one found within our limits.

Genus Astrangia M.-Edw. and Haime.

Astrangia M.-Edw. and Haime, Comptes-rendus, xxvii. p. 496 (1848).

Corallum incrusting, the corallites arising from an expansion of the base of the parent, and sometimes from the walls or margin, forming either clustered groups or aggregated, astrea-like masses, sometimes with rising branches. Walls naked and costate. The cells are circular except where crowded, deep, with numerous subequal septa, which are all dentate, those of the last cycle curved ; columella papillose ; dissepiments few. The polyps when expanded are subtransparent, and rise to a considerable distance above the cells. The tentacles are long, slender, covered by minute white warts, consisting of lasso-cells, and have a knob at the tip.

Astrangia astræiformis M.-Edw. and Haime.

Astrangia astræiformis M.-Edw. and Haime, Ann. des Sci. Nat., 3d ser. xii. p. 181 (1850).

Corallum composed of closely aggregated corallites, united nearly to their summit, spreading over and incrusting the surface of shells, and, by continued growth, forming astrea-like masses of considerable thickness, which often rise into numerous short irregular branches. In these, besides the marginal buds that arise from the basal expansion, many originate from the sides of the parent polyps and some even from the margin of the disk. The cells are widely open, deep, and narrow at the bottom. Columella well developed, papillose, the papillæ confounded with the inner teeth of the septa. Septa much narrowed at the top, in three complete cycles, often with some of a fourth ; those of the third cycle are well developed, and curve towards those of the preceding one, uniting with them interiorly; all of them have the sides granulated and the edges sharply dentate. Costæ well marked near the margin. Thickness or height above the base, often two inches; diameter of the cells about .18 inch. (Coll. Mus. Comp. Zoöl.)

Charleston, S. C. (L. Agassiz); Beaufort, N. C. (A. S. Bickmore).

This species often incrusts shells that are inhabited by hermit crabs.

Astrangia Danæ Agassiz.

Astrangia Danæ Agassiz, Proc. Amer. Association, ii. p. 68, 1849 (*non* M.-Edw. and Haime). *Astrangia astreiformis* Leidy, Journal Acad. Nat. Sci. Philadelphia, 2d series, iii. p. 135, 1855 (*non* M.-Edw. and Haime).

In its mode of growth and general form this species resembles the preceding, but does not form so thick masses and the corallites are less closely united. Their walls are smoother, with less distinct costæ. The cells are not so deep and have a more open appearance, owing both to the much less developed columella, which is, however, more distinct from the septa and composed of larger papillæ, and to the narrower septa of the fourth cycle, which do not extend half-way to the centre. The polyps are very exsert in expansion, with about twenty-four long slender tentacles. The disk is usually convex or conical. Color of polyps white or light flesh-color, diaphanous. (Coll. Mus. Comp. Zoöl.)

Long Island Sound.

This species incrusts rocks from just below low-water mark to ten fathoms, and is very abundant in some localities. It thrives well in the aquarium, eating oysters and other mollusca with avidity.

Prof. Agassiz has an excellent series of unpublished plates, representing the polyps of this species in various attitudes, with the details of its anatomy.

Family Oculinidæ Milne-Edwards and Haime.

Genus Oculina Lamarck.

The corallum while young spreads laterally by basal budding, forming an incrusting base, from which branches arise in a tufted or arborescent manner. Corallites arranged somewhat spirally on the branches, separated by a compact cœnenchyma, the surface of which is nearly smooth midway between the cells, but marked by radiating costæ near them. These are rather deep, with a papillose columella and pali before all the septa except those of the last cycle. Edges of the septa entire or nearly so, moderately exsert.

Oculina arbuscula Agassiz.

In this species the corallum is arborescently branched from near the base, which is spreading and incrusting. The trunk is short, very thick, and divides soon into several large diverging branches. These are round, usually somewhat bent, gradually tapering, and very rapidly divide dichotomously into two or three spreading branchlets, which are curved and taper rapidly to the blunt tips. Corallites a little prominent, generally with perpendicular walls, arranged spirally around the branches, not crowded; cells rather large, and deep. Septa in four cycles, those of the last generally incomplete. The principal ones are narrow, nearly perpendicular within, their summits somewhat exsert, rounded. Columella slightly developed, pali rudimentary or but slightly prominent. Costæ distinct only near the cells; surface of the cœnenchyma finely granulous, often convex between the cells. Unbleached specimens are light yellowish brown. In a specimen eight inches high the principal branches are .75 of an inch in diameter; the cells about .12.

Charleston, S. C., off the bar, L. Agassiz. (Coll. Mus. Comp. Zoöl.)

Oculina implicata Agassiz, MS.

This species forms dense clumps of strong, crooked, intricately coalesced branches, which are round and obtuse at the ends when free. Cells rather small, deep, very little prominent, arranged somewhat near together, in spiral lines; septa in three cycles, very narrow, the inner edge perpendicular, scarcely exsert. Columella papillose, little developed. Pali scarcely apparent. Surface of the cœnenchyma between the cells finely granulous, immediately around the cells marked by faint costal radii. The clumps are six or eight inches in diameter and about the same in height; the branches about half an inch in diameter; cells one tenth.

Cape Hatteras and Beaufort, N. C., thrown upon the beach after storms. (Coll. Mus. Comp. Zoöl.)

Among a large number of specimens of this species I have seen none that are perfect, all of them being more or less worn. It is closely allied to the preceding, notwithstanding the great differences in its mode of growth and appearance of the cells, and, when large series of specimens of each can be obtained, may prove to be only a peculiar form of the same species.

Geographical Distribution.

The eastern coast of North America has been divided into six regions, each characterized by a peculiar assemblage of animals, some of which are confined exclusively to the region in which they belong, while others may extend beyond those limits in either direction, and occur more or less abundantly in two or more of the subdivisions. These regions have been called *provinces* by Dana, and *faunæ* by Lütken and other writers. The limits of most of them are well marked, and have been clearly defined by most naturalists who have recently written upon this subject. The Polyps have not, however, been hitherto sufficiently well known to be made useful to any great extent in these investigations. The facts which I am now able to present accord perfectly with those that have been derived by others from the study of the Crustacea, Mollusca, and Acalephs.

The most northern part of the American coast from Newfoundland to the Arctic Ocean belongs to the great Arctic Realm or Kingdom. This has not yet been examined to an extent sufficient to distinguish many of its subdivisions or *faunæ*, yet it has recently been shown by Mr. A. S. Packard, Jr.,[1] that the southern portion should be distinguished from the more northern. The former he has named very appropriately the Syrtensian Fauna. To the southward of the arctic kingdom we have the sub-frigid region, extending as far south as Cape Cod along the coast, and impinging upon some of the outer banks or shoals still farther south. This division has been called the Nova Scotia Province by Dana,[2] which is changed to Acadian Fauna by Lütken.[3] The cold-temperate region, extending from Cape Cod to Cape Hatteras, has been called the Virginian Province by Dana. This and the preceding are together nearly equivalent to the Pennsylvanian Region of Milne-Edwards. The warm-temperate region, from Cape Hatteras to the northern part of Florida, has been generally called the Carolinian Province or Fauna. The tropical region south of this, including the southern part of Florida, Bermuda, and most of the West India Islands, does not come

[1] Canadian Naturalist and Geologist.

[2] Crustacea of the U. S. Expl. Exp., by J. D. Dana, 1853, vol. iii. p. 1564.

[3] Oversigt over Grönlands Echinodermata, af Chr. Fr. Lütken, Kjöbenhavn, 1857, p. 91.

within the province of the present paper. It has been called the Floridian Province by Dana, and the West Indian Fauna by others. The following brief conspectus will show the relations of these faunæ more clearly.

Syrtensian Fauna. This embraces the southern coast of Labrador, the Straits of Belle-Isle, the Banks of Newfoundland, banks off the mouth of the Bay of Fundy, and St. George's Bank. The three polyps known from this fauna appear to be circumpolar, but are not found in the next.

Acadian Fauna. This extends along the coast from the mouth of the St. Lawrence to Cape Cod, embracing partially the island of Anticosti, the Magdalen Islands, Breton Island, and perhaps the southern coast of Newfoundland, and extending to Nantucket Shoals, and, as has been suggested by Dr. Stimpson, to a bank off the coast of New Jersey, from which *Zoanthus parasiticus* has been obtained, associated with many northern species. Of the ten species found in this fauna, but one (*Metridium marginatum*) is known to extend into the Virginian; and one other (*Rhodactinia Davisii*) probably occurs in the Syrtensian.

Virginian Fauna. This embraces the whole extent of the coast from Cape Cod to Cape Hatteras. Five species are considered as peculiar to this fauna.

Carolinian Fauna. This extends from Cape Hatteras to St. Mary's River, Florida. There are eighteen species found in this region, none of which are known to extend to either of the others, or to the West Indian.

Syrtensian Fauna.

Alcyonium rubiforme Dana. Banks of Newfoundland.

Primnoa Reseda Verrill. Mouth of the Bay of Fundy in deep water; St. George's Bank, C. H. Fifield.

Paragorgia arborea M.-Edw. Mouth of the Bay of Fundy, Dr. Wm. Wood.

? *Rhodactinia Davisii* Agassiz. Specimens of an Actinian too imperfect for accurate determination, but resembling this species, were collected on the coast of Labrador by Mr. A. S. Packard, Jr.

Acadian Fauna.

Alcyonium carneum Agassiz. Breton Isl., Nova Scotia, 10 f., rocks, Anticosti Expedition;[1] Grand Menan, 15 f., shelly, Dr. Wm. Stimpson; Eastport, Me., low water to 25 f., rocky and shelly bottoms, abundant, A. E. Verrill; Casco Bay, near Portland, Me., E. S. Morse; Massachusetts Bay, L. Agassiz, Wm. Stimpson; Provincetown, Mass., Capt. Atwood.

Bunodes stella Verrill. Grand Menan, N. B., and Eastport, Me., in crevices of ledges at low water, abundant, A. E. Verrill; Mt. Desert, Me., at low water, A. E. Verrill; Cape Elizabeth, Me., in rocky pools at low water, partly covered by sand, E. S. Morse.

Rhodactinia Davisii Agassiz. Grand Menan, from low water to 30 f., Wm. Stimpson, A E. Verrill; Eastport, Me., on ledges at low water, and from 2 to 20 f., rocky, abundant, A. E. Verrill; Massachusetts Bay, L. Agassiz; Nantucket Shoals, L. Agassiz.

Metridium marginatum M.-Edw. Gaspé, Canada East, J. W. Dawson; Breton Isl., N. S., Anticosti Expedition; Grand Menan, Wm. Stimpson, A. E. Verrill; Eastport, Me., 2 f., rocky, A. E. Verrill; Mount Desert, Me., low water to 3 f., rocky, abundant, A. E. Verrill; Portland, Me., on piles at low water, E. S. Morse; Swampscot, Mass., on rocks and in pools

[1] Conducted by Messrs A. Hyatt, N. S. Shaler, and A. E. Verrill, 1861.

at low water, A. E. Verrill; Nahant, Mass., L. Agassiz. This species also extends to the Virginian Fauna.

Edwardsia sipunculoides Stimpson, MS. Grand Menan, at low water, Wm. Stimpson; Eastport, Me., in gravelly mud under stones at low water, abundant at one locality, Wm. Stimpson, A. E. Verrill.

Edwardsia sulcata Verrill. Chelsea Beach, Mass., thrown up by a storm, A. S. Packard, Jr.

Bicidium parasiticum Agassiz. Eastport, Me., on under surface of *Cyanea arctica*, A. E. Verrill; Nahant, Mass., on *Cyanea arctica*, L. Agassiz, A. Agassiz.

Ilyanthus lævis Verrill. Eastport, Me., L. Agassiz.

Zoanthus americanus Verrill.[1] Bank off the coast of New Jersey, lat. 40° N., long. 73° W., 30 f., fine sand, Capt. Gedney.

Arachnactis brachiolata A. Agassiz. Nahant, Mass., swimming at night near the surface of the water, A. Agassiz.

Virginian Fauna.

Leptogorgia tenuis Verrill. Bay of New York, Smithsonian Institution.

Metridium marginatum M.-Edw. Naushon, Mass., A. Agassiz; Point Judith, R. I., J. Leidy; near New York City, Mr. Damon.

Actinia (?) rapiformis LeSueur. Egg Harbor, N. J., buried in sand, C. A. LeSueur.

Halcampa albida Agassiz MS. Nantucket Isl., buried in sand at low water, B. T. Morrison, J. Rice.

Ilyanthus (?) neglectus (Leidy). Atlantic City, N. J., in mud, J. Leidy.

Astrangia Danæ Agassiz. Point Judith, R. I., J. Leidy; off Gay Head, L. Agassiz; Naushon, Mass., A. Agassiz.

Carolinian Fauna.

Telesto fruticulosa Dana. Charleston, S. C., L. Agassiz; Stono Inlet, Dr. J. W. Page; Savannah, Georgia, L. Agassiz.

Gorgonia humilis Dana. Charleston, S. C., L. Agassiz.

Leptogorgia virgulata M.-Edw. Beaufort, N. C., Wm. Stimpson, A. S. Bickmore; Charleston, S. C., L. Agassiz; Stono Inlet, Dr. J. W. Page; coast of Georgia, Dr. J. W. Page; St. Mary's River, Florida, Williams College Expedition.

Muricea pendula Verrill.[1] Charleston, S. C., off the bar, L. Agassiz.

Titanideum suberosum Agassiz MS. Beaufort, N. C., Wm. Stimpson; Charleston, S. C., L. Agassiz; Stono Inlet, Dr. J. W. Page.

Renilla reniformis Cuv. Beaufort, N. C., Wm. Stimpson; Charleston, S. C., at low water, L. Agassiz.

Bunodes cavernata Verrill. Charleston, S. C., L. Agassiz.

Cereus sol Agassiz MS. Beaufort, N. C., A. S. Bickmore; Charleston, S. C., L. Agassiz.

Dysactis pallida Agassiz MS. Beaufort, N. C., A. S. Bickmore; Charleston, S. C., L. Agassiz.

Aulactinia capitata Agassiz MS. Beaufort, N. C., A. S. Bickmore; Fort Macon, N. C., Dr. S. Cabot; Charleston, S. C., in sand at low water, L. Agassiz.

Ilyanthus chloropsis Agassiz MS. Charleston, S. C., L. Agassiz.

Halcampa producta Stimpson MS. Charleston, S. C., Wm. Stimpson.

[1] See Addenda, page 45.

Cerianthus americanus Agassiz MS. Beaufort, N. C., Wm. Stimpson; Charleston, S. C., in mud at low water, H. J. Clark, L. Agassiz.

Antipathes Boscii Lamx. Edisto Isl., S. C., L. Agassiz.

Antipathes alopecuroides Ellis. South Carolina, J. Ellis.

Astrangia astræiformis M.-Edw. and Haime. Beaufort, N. C., A. S. Bickmore; Charleston, S. C., L. Agassiz; St. Mary's River, Florida, Williams College Expedition.

Oculina implicata Agassiz MS. Cape Hatteras, L. Agassiz; Beaufort, N. C., A. S. Bickmore.

Oculina arbuscula Agassiz MS. Charleston, S. C., off the bar, L. Agassiz.

Analytical Table.

The following table is intended to aid those in the determination of the genera who may not already be familiar to some extent with the classification of polyps. It will apply only to those genera that are included in the present paper.

A. Tentacles eight, pinnately lobed (1) (*Alcyonaria*).
B. Tentacles six, or multiples of six, simple (7) (*Zoantharia*).

Alcyonaria.

	Page
1. Polyps forming a free, moving community (*Renilla*)	12
1. Polyps forming an attached community (2)	
2. Individuals arranged around a central axis (3) (*Gorgonidæ*)	
2. Individuals aggregate, destitute of a common axis (6) (*Alcyonidæ*)	

Gorgonidæ.

3. Axis firm, spiculose, cork-like (*Titanideum*)	10
3. Axis soft, porous, scarcely distinct (*Paragorgia*)	10
3. Axis solid and strong (4)	
4. Cells papilliform, covered with imbricated spicula (*Muricea*)	8
4. Cells bell-shaped, covered with scale-like spicula (*Primnoa*)	9
4. Cells without external spicula (5)	
5. Cells prominent, verruciform (*Gorgonia*)	6
5. Cells scarcely prominent (*Leptogorgia*)	7

Alcyonidæ.

6. Polyps forming a fleshy, lobed community (*Alcyonium*)	3
6. Polyps forming a tubulous, branching clump (*Telesto*)	5

Zoantharia.

7. Polyps secreting a solid, horn-like axis (*Antipathes*)	36
7. Polyps forming solid calcareous corals (8) (*Astræaria*)	
7. Polyps fleshy, destitute of solid corals (9) (*Actinaria*)	

Astræaria.

8. Coral branching, solid within (*Oculina*)	40
8. Coral incrusting, cellular within (*Astrangia*)	39

Actinaria.

9. Polyps compound (*Zoanthus*)	34
9. Polyps simple (10)	

10. Basal disk wanting, polyp swimming freely (*Arachnactis*) 33
10. Basal disk wanting, polyp sedentary (11)
10. Basal disk distinct (14)
 11. Tentacles numerous, of two kinds (*Cerianthus*) 32
 11. Tentacles numerous, marginal only (12)
 11. Tentacles twelve, of one kind (13)
12. Column of uniform texture (*Ilyanthus*) 26
12. Column with a thickened epidermis in the middle (*Edwardsia*) 27
 13. Mouth with prominent lobes (*Bicidium*) 31
 13. Mouth simple, column with suckers (*Halcampa*) 29
14. Disk frilled, tentacles very numerous, fringe-like at the margin (*Metridium*) 21
14. Disk plain, tentacles slender, not contractile (*Dysactis*) 26
14. Disk plain, tentacles contractile (15)
 15. Walls covered by crowded verrucæ (*Bunodes*) 15
 15. Walls with distant verrucæ; tentacles large (*Rhodactinia*) 18
 15. Walls verrucose above; margin with trilobed verrucæ (*Aulactinia*) 20
 15. Walls smooth or with inconspicuous suckers (16)
16. Column smooth, with a thickened fold above, tentacles few (*Metridium*, young) 21
16. Column with suckers, but no fold, tentacles numerous (*Cereus*) 24
16. Column smooth throughout, tentacles few (*Rhodactinia*, young) 18

Explanation of Plate I.

(Figures 10, 11, from nature, by Wm. Stimpson; 8, 9, 14, 15, by the author; the others by E. S. Morse.)

Figs. 1–8, *Bunodes stella:* 1–3, young when first excluded; 4, adult polyp when contracted; 5–7, different views of the expanded polyp; 8, magnified view of the mouth, *a a* the two primary radii, corresponding with the antero-posterior axis, *b b* and *c c* the other radii of the same cycle.

Fig. 9, *Rhodactinia Davisii*, mouth somewhat enlarged; the letters correspond to the same parts as in fig. 8.

Figs. 10, 11, *Halcampa producta:* 10, polyp when taken from the sand and allowed to expand; 11, form when expanded in its burrow.

Figs. 12, 13, *Edwardsia sipunculoides:* 12, polyp of the natural size drawn from a specimen somewhat contracted in alcohol; 13, disk and tentacles considerably enlarged.

Figs. 14, 15, *Bicidium parasiticum:* 14, polyp natural size; 15, enlarged view of the disk and mouth.

Addenda.

Since this paper went to press, I have been able to examine the "Mémoire sur les Coralliaires des Antilles," by Duchassaing and Michelotti, Turin, 1860, a work not previously accessible to me. These authors have described a species under the name of *Muricea elegans* (p. 19), which is apparently identical with *Muricea laxa* Verrill, recently described in the Bulletin of the Museum of Comparative Zoölogy. For the species called by the same name in the present paper I would, therefore, propose the name *Muricea pendula*. In the same work (p. 50) the name *Zoanthus parasiticus* has been preoccupied. The species herein described under that name I propose to call *Zoanthus americanus*.

II. *On* Morphology *and* Teleology, *especially in the Limbs of Mammalia. By* BURT G. WILDER, S.B.

Read June 3d, 1863.

T is not many years since the very title of this paper would have been enough to insure its remaining unread by most professional men, or, if read, to excite their derision of him who should have so wasted his time as to write, or even think, of such vain abstractions, fit expressions of the useless imaginings of the half-crazy enthusiast Oken, and his only less crazy, because less gifted, disciples. And there are, even now, stern votaries of practical science who would scorn any attempt to raise their eyes above the mere facts of Nature which are as patent to the ignorant vision as to their own, and who refuse to seek an insight into those hidden relations, for the correct understanding of which their superior knowledge might be the surest preparation.

But there are others, and their number is increasing, who, believing in the existence of a general plan underlying all the more external phenomena of Nature, are willing to try to comprehend it in its greater and lesser manifestations; and they, in reading the "Physio-philosophy," may be able to discern, amongst much that is fanciful and absurd, many suggestions of a sound as well as original and striking philosophy. No apology, therefore, is now required for thinking or writing upon subjects which have engaged the attention of the most celebrated students of both animal and vegetable anatomy, and which, I am convinced, will, erelong, be acknowledged to be as essential to the proper understanding of these sciences as the classifications of which they form the only true basis.

To express the various relations which have been observed among the several parts and their functions, of animals and plants, the following terms have gradually come into use: *homology*, *affinity*, *morphology*, *analogy*, *teleology*; to these may be added *physiology*, which, though a term long employed to denote the general study of *function*, has now acquired a certain technical significance, equivalent to the more strictly scientific, and therefore preferable term, *teleology*.

Analogy is used to indicate similarity of function, which may be very close, when yet the two parts are widely dissimilar in structure; as, for instance, the organs of aërial locomotion of a bird and a butterfly, which both go by the name of *wings*, though one is built upon the vertebrate, and the other upon the articulate plan of structure. Of course the structure may correspond with the external form and function, and then the analogy is more complete, as between the foot of man and that of a bear.

Now the *general* function or use of a part is its *physiology*; the *special* or principal use of a part is its final cause or end, or *teleology*; and parts which are teleologically similar are said to be *analogous*.

It is evident that the external form and the function must to a great extent correspond, at least much more fully than either may with the internal structure, and here we observe the first distinction between the two groups of terms given above; for this intimate structure and arrangement, in other words, the pure anatomy of anything, is its *morphology*, and parts which are morphologically similar are said to be *homologous*; there is *homology* or *affinity*, or, in still plainer words, more or less *identity of structure* between them; and here again, as was seen in speaking of analogy, parts or organs which are homologous, that is, identical in their general plan of structure, may be intended to perform functions most diverse, and their outward forms be in like degree modified. For instance, the fin-like flipper of the seal bears little resemblance to the anterior extremity of the ape, and yet they are identical in their general structure, — they are homologous.

It may have been inferred, from what has been said above, that we have necessarily two systems of nomenclature, according as morphology or teleology is taken as the basis. For it is the latter which confers common and popular names on objects of Natural History, and arranges them in a way which, though convenient enough under ordinary circumstances, utterly fails of precision for all scientific purposes; and the anatomist and zoölogist soon learn that morphology alone must be their guide in scientific nomenclature. Thus the name *fish* is applied to several animals in structure very unlike the true Pisces, merely because, like that group of Vertebrates, they live in the water: to certain Radiates, as the star-fish and sun-fish; to Articulates, as the cray-fish; and, formerly, even to the whale, an air-breathing Mammalian Vertebrate. So among Articulates, the monosyllable *fly* forms the ending of the common names of many insects, as butter-fly, dragon-fly, harvest-fly, ichneumon-fly, members respectively of the sub-orders Lepidoptera, Neuroptera, Hemiptera, and Hymenoptera, though it is only to the Diptera that the name *fly* properly belongs.

These are zoölogical ambiguities; anatomical ones are even more frequent. All organs of aërial locomotion are commonly called *wings*, whether they are articulate or vertebrate in type, or whether, within the latter group, they are avian or mammalian, as those of the bats; and the same is the case with other parts and organs, thorax, abdomen, heart, liver, and stomach.

I could not well pass over this most important branch of the subject; but the great necessity to the philosophical naturalist for a revised anatomical nomenclature has already been strongly urged by Professor Agassiz, before the Boston Society of Natural History.[1] Premising that the members of the four great types have nothing in common beyond their all being animals, and that, therefore, no parts, however similar in function, can possibly be homologous in animals belonging to any two of these types, he showed the propriety of restricting the common names mouth, stomach, heart, and the like, to one of these groups, the Vertebrates perhaps, and of applying other names to the analogous parts in the other three types. Perhaps the change should be even greater than this; for, since these new names would of course be classical in their derivation, and the common ones, though scientifically restricted, would in general discourse retain the same loose application, it would seem better to employ new terms for the various parts and organs in *each* of the four types, leaving the common ones as they are now. It is evident that much remains to be done in this matter of anatomical nomenclature, and that it is of as much importance to the anatomist as are the names of the animals themselves to the zoölogist.

Popular descriptive zoölogy concerns rather the teleological characters of animals, while the strictly scientific and systematic arrangements are based upon anatomy, and thus upon morphology.

We have noticed one distinction between the terms given above: that morphology and homology both refer to *structure*, while teleology and analogy both refer to *function*. Affinity is merely a common synonym for homology, and may therefore be omitted. And now the four principal terms pair off on another basis; morphology and teleology are *absolute* terms, as it were, and may refer to the structure or the function of but a single part or organ;

[1] See also his section on Morphology and Nomenclature, in Contributions to the Natural History of the United States, vol. iii. chapter ii. section iv.; also section iii. p. 69.

while homology and analogy are the corresponding *relative* terms, and necessarily refer to two or more parts or organs which are morphologically or teleologically similar.

Morphology is not exactly synonymous with anatomy, for the latter term embraces *all* the characters of a part, external as well as internal; so that, strictly speaking, parts which are anatomically similar, are likewise physiologically so. But morphology refers rather to the general plan of structure of a part, without altering which, great modifications may be wrought in its outward aspect, with reference to the various functions it is to perform.

In like manner teleology is not exactly synonymous with physiology, for the latter term embraces all the functions which can be performed by the part, the less as well as the more essential, otherwise the converse of the previous proposition would be true, and parts which were teleologically similar would be also morphologically similar, which is not the case; every form or *morph* has a certain general use or function proper to it, and which may remain under many of its modifications.

It is thus of the utmost importance to discriminate between essential structure or morphology, and general structure or anatomy; so also between special function or teleology, and general function or physiology.

Most objects, whether animal or vegetable, and their various organs, possess more than one attribute; their anatomy is compound; their morphology is that simple essential structure which, as a foundation, underlies the more external attributes, one of which is specially developed for the performance of the function from which it has its name; by an easy transfer, the name is finally associated in our mind with the morphology; and then, if this primary attribute be overshadowed by an excessive development of one of the secondary attributes, although the function of the part may be entirely changed, yet, as the essential structure is still recognizable through the external mask, the name is unchanged. Morphologically it is the same, though teleologically it may be quite another thing. For examples, and, if I remember rightly, a clearer explanation of this transfer of the name of a part, see the opening paragraphs in Owen's Report on the "Homologies of the Vertebrate Skeleton," to the British Association for the Advancement of Science for the year 1846.

With things inanimate the teleology is the use which is made of them. As a familiar illustration, the round Dutch cheeses, used as missiles by one of the parties in a sea-fight years ago, were none the less cheeses, and perhaps excellent ones, because on this occasion put in the place of round shot, thus making the use for which they were intended and named subservient to one rendered possible by a secondary attribute, their extreme hardness. As a second example, far too familiar in these days, a shell may strike a victim before it explodes, and thus be teleologically a solid shot, while yet its structure, as adapted to its intended use, remains unaltered.

It is needless to multiply illustrations. Whenever anything, without alteration in its essential structure, even though its external form be somewhat modified, fulfils a function other than that for which it was originally intended, then its morphology and its teleology, previously coinciding, are at variance.

It thus appears that the teleology may differ from the morphology, as the *spirit* of the law from the *letter* thereof, as the *expression* of a face from the *features* composing it, as the *practical* from the *technical* or *theoretical*, as the *actual* or *virtual* from the *nominal* or *ostensible*; in short, as the *thing* may differ from its *name*, the *de facto* from the *de jure*.

Morphology is *substantive*; teleology is *adjective*. Morphology is the *noun*; teleology is its *modifier*. And as the noun with its modifier may be regarded as a compound substantive, and may thus be further modified by other adjectives, so in comparative anatomy, nothing is absolutely morphological or teleological, but only with reference to some organ or function more general above, or more special below; it is the possibility of the configuration of an organ being modified without change to a corresponding degree in the internal structure and arrangement of parts. Zoölogically speaking, it is the possibility of specific modifications of generic ideas, so that from a limited number of substantives, by adjective additions, are made designations of many more objects; and few at this day dare affirm that this is only a matter of human invention for human convenience.

Every genus represents the morphology of the species embraced within it, and they are teleological modifications of the generic idea; now this is the relation between each higher group and the next lower; the further we recede from the species, from the individual in fact, the more occult and ideal becomes the morphology, till we reach at last the four great groups called types, which, as we shall see hereafter, may even be represented by geometrical figures. How far are these removed from the living sentient individuals which form the other zoölogical extreme! And yet it does not follow that the existence of the order, the class, or even the type, is any less real and actual than that of the species or of the individual; it is less *material*, but none the less *substantial;* in fact, the higher the group, the more real and enduring it is, for it exists in all the members of all the groups embraced within it, though it would exist if it had but a single individual representative.

It was said above, that morphology refers only to the general plan of structure; in a certain sense this is so, since it refers to a more hidden interior grade of anatomical characters than those which ordinarily appear upon the surface. The zoölogist will see that each of his categories of structure is based upon a different grade of morphology; thus there is a type morphology, the most interior of all, beyond which there are no homologies, but within which are more and more apparent ones, the class homologies, the ordinal homologies, the homologies of the family, genus, and species. I do not mean to say that these groups, as at present characterized by Professor Agassiz, or by any other naturalist, are the true ones, or that they should bear these names, or even that there is just this number of categories of structure; but I do believe that a classification does exist in Nature entirely independent of human thought; that the various kinds of groups in this natural classification are founded upon categories of structure radically distinct, not at all merging or interchanging; and finally, that these categories are simply statements of the various grades of morphology, upon which alone classifications are based.

But though this seems to carry us away from direct material function or use, it by no means negatives the idea that each natural group does really represent some use in the grand operations of Nature. Indeed, this would follow as the converse of what was said above, that every higher group represents the morphology of the groups next below, which are themselves teleological modifications of it; conversely, each lower group is, with reference to the next higher, more directly teleological, and increasingly so as we approach the species and the individual. Even the types, ideal and unsubstantial as they seem, represent the four ways in which the powers of sensation and voluntary motion may be embodied and brought into use in the economy of Nature: the idea of an animal is distinct enough in our minds, but so hard to put into words that no really satisfactory definition has ever been proposed. What better evidence of the immaterial character of the principle which distinguishes the animal from the vegetable and mineral subdivisions of Nature.

It seems at first rather strange that the progress in philosophical *anatomy* may be estimated by the more frequent occurrence of the term *homology*, especially in the works of Professor Owen, who has done so much toward dispelling the mystery and almost odium attached to the subject, and has cleared up some of its most difficult problems,[1] while the philosophy of *botany* is measured by the term *morphology*, although it has apparently never been perceived that they are corresponding terms, the one *relative*, the other *absolute*.

But much of the wonder vanishes when it is remembered that the unit of vegetable structure is very simple, consisting, in the Dicotyledones, of the phyton, or leaf with its segment of stem; and that out of these, by wonderful transmutation and combination, the whole plant is built up. The morphology of a vegetable organ is enunciated when it is shown in what manner it is referable to the typical phyton; and since so few elements compose this, seldom would there arise questions of special and thus of general or serial homology. But with animals the case is otherwise. Having left the simple cell, of which vegetables also are composed, we find at once that their bodies are made up of many organs which cannot possibly be referred to any one unit of structure. The nervous, circulatory, and digestive systems are entirely isolated from each other, and differ, not only physiologically, but microscopically and chemically. Still more complex are the relations existing in the muscular and osseous systems, as presented in the Vertebrates; for here the skeleton is made up of a series of segments called vertebræ, which are themselves composed of smaller parts or elements having definite relations and bearing distinct names, and by variation in the number, size, and shape of which an almost endless diversity is produced. And now the questions which arise are emphatically those of *relation*, of *homology*: what parts represent each other in different animals; what position one element of a vertebra holds with reference to the others in the same; and what elements in two different vertebræ repeat each other; — questions of special, of general, and of serial homology, respectively. It is not, then, so strange that botanists have used the *absolute* term *morphology* with reference to the objects of their study, when so few parts or elements compose the *morph* or type of which the members of any one large group are built up, as that the anatomist, in his anxiety to determine the manifold relations existing in the bodies of animals, should look upon morphology only as the necessary guide to the more difficult questions of homology, which in itself implies more than one morph.

Teleological diversities are as of *more* and *less*, and the resulting varieties communicate with each other only by continuity; by *continuous* degrees.

Morphological diversities are as of *interior* and *exterior*, as of *superior* and *inferior*, and the resulting varieties communicate only by *contiguity*; by *discrete* degrees.

Here, if rightly appreciated, is contained the essence of two most interesting and not always easily understood generalizations, which are potent weapons of the modern zoölogist: the one defensive of his belief in a natural classification, the other offensive against those who assert the existence of a regular, uninterrupted succession of organic forms from lowest to highest, because, forsooth, they cannot see how else creation was effected; thus profanely daring to limit Infinite power by their own wilfully diminished capacity.

[1] In his elaborate and admirable *Report on the Homologies of the Vertebrate Skeleton*, Professor Owen defines three relations of homology: "1st. When a part is said to occupy a certain position in its vertebra, its *general* homology is enunciated. 2d. When such a part is said to repeat in its vertebra that which occupies a corresponding position in another vertebra before or behind, its *serial* homology is given. 3d. When a part is said to have the same relations in two different animals, then its *special* homology is indicated."

These definitions, as we shall see, do not cover *all* relations of homology.

These are, 1st, the law of Parallel Relations; and, 2d, the teleological rising above or sinking below their morphological level, of certain groups or species or individuals, whereby they *seem* to be of a higher or lower grade than the rest of the group of which they are generally the extreme aberrant forms.

Illustrations of either of these laws are almost superfluous; of the former many will have occurred to the naturalist who observes similar functions exercised by animals belonging to different groups, or even types: — the aërial bird and butterfly; the heavy, graminivorous cattle among Mammalia, and the phytophagous Scarabei among Coleoptera; the monkey and the parrot; the whole type of Articulates, and the vertebrate class Aves; the type of Mollusks, and the vertebrate class Reptilia; the three classes of Articulates, with the three orders of its highest class, Insecta; and, finally, the striking parallelism between the orders of the two groups of Mammalia, called by Dana Megasthenes and Microsthenes, (American Journal of Science and Art, vol. xxxv. p. 70,) with the less evident one between the Altrices and the Precoces among birds. Between all these pairs of groups is so evident a similarity as to have suggested the term "Parallel Relation;" but it is to be observed that the relation is one of *analogy*, not *homology;* that the differences are morphological, and the resemblances are comparatively teleological, while between component parts of the same group the resemblances are morphological and the differences teleological.

Many insects are *physiologically* more highly organized than the lowest fishes, and the eagle seems a creature vastly superior to the whale; but in each case the groups to which, according to their essential structure, the insect and the eagle belong, are, *as groups*, on a plane below the fishes and the mammals. The two relations are commonly expressed by representing the groups by parallel vertical lines; there may be such morphological differences between the groups as to clearly indicate which are higher and which lower, but the lines may be overlapped, to show that the lowest in one group is teleologically inferior to the highest of the next group, though, as said above, there would be no doubt concerning the groups taken as wholes.

There is not, at least among the higher groups, any such lineal shading off into each other as to afford any support to the idea of a regular, uninterrupted succession of organic forms, whether zoölogical or genealogical. Nor does the present state of Paleontology furnish the disciples of Darwin much assistance in this respect.

Position may determine a morphology in addition to that dependent upon structure, and nowhere is this more clear than with the teeth of Mammalia. Professor Owen, in his Odontography, has shown that every classification of these organs based upon their form, and thus upon their special masticatory function, utterly fails in precision on general application, and that the position of the teeth in the jaws is the only safe guide to their arrangement. In this case, it so happens that the teeth were originally named, from their shape and function, *incisors*, *canines*, and *molars;* and this is the order in which they stand in the jaws from before backward. But, while this would answer very well in designating the corresponding teeth in two animals having the same number, and where the variations in form were slight, it utterly failed, even in the hands of Cuvier, accurately to determine such correspondence when applied to the whole range of the mammalian series.

Without entering into details, which are given in abundance in the Odontography, it may be said that the teeth collectively are distinguished from all other parts and organs, hard or soft, by a peculiar structure or morphology of their own; but that, to ascertain the limits of the several groups of teeth in the jaws of a single species, or to point out corresponding or homologous teeth in animals having a different number, their position in the jaws is the only safe standard, this constituting a minor morphology.

Thus we have teeth *morphologically canine*, but *teleologically incisor*,—the outer pair of teeth in the incisive row in the lower jaw of the typical Ruminants, (sheep, cattle, &c.;) and, on the other hand, we have teeth which are *morphologically incisor*, but *teleologically canine*,—the only pair of teeth in the intermaxillary bone of the Camelidæ, in which aberrant group of Ruminants the lower canines above mentioned assume their proper form and function, as if to compensate for the absence of horns.

And this brings us at once to the consideration of the important question, whether every anatomical generalization is not an expression of morphology; whether every grouping of facts which we regard as natural, and which enables us better to comprehend and arrange other facts, is not morphology in the strictest sense of the word. If so, as I believe, then all anatomy is or should be morphology; for all particulars should be studied with reference to generals already ascertained or to be elucidated. And thus morphology comes to be a very simple thing, and not at all a mystery, and will be avoided only by those who confound rational philosophy with unprofitable imaginings of pretty, pleasing fancies. The Creator did not work with barren isolated facts; and only those who strive to rise above these, will ever gain an insight into the way in which He did work, with general laws first established, but only with reference to the particular ultimate facts which were grouped around them.

In the human body must exist just such complication of structure and arrangement of parts as best adapt it to be the fit and willing agent of the human mind; and as this is, if not always actually, yet potentially, on a plane superior to that of brutes, so we are prepared to find in its fleshy covering a perfection of structure and harmonious arrangement of parts, which, in their totality, far surpass what we observe in inferior animals.

In animals, it is true, there may often exist a higher development of one function or class of functions; but this, as we shall see, is always at the expense of the rest, besides marring that beauty of proportion which is really an important element in the human frame. The fish and the whale swim better than man, but the form and structure requisite for this simplest mode of locomotion render every other impossible; even the limbs of the seal, though rather more free, are awkward imitations of anything unless it be paddles. The teeth and stomachs of the strictly carnivorous or herbivorous animals are better adapted for seizing and lacerating or chewing, and for digesting certain kinds of food; but the necessary limitation, as regards other kinds, is an obvious imperfection, taking the creature as a whole. The bird flies through the air with a velocity which man will probably never equal by any mechanical contrivance; but the necessary concentration of weight between the wings makes the anterior and posterior extremities mere bony supports for air and earth, the head taking the place of the hand as an organ of prehension, and becoming thereby incapable of speech or expression. The great strength of the ox, and the speed of the horse or of the deer, are gained by such an arrangement of the muscles of the limbs, and modification of their bony frame, as almost to preclude any other motion than simple flexion and extension forward and backward, involving also the loss of prehensile power in the hand. Even the ape, whose structure is so perfectly fitted for climbing, is, so far as regards the location of the organs of prehension and of progression, a man reversed;[1] and the power of free rotation in the forearm, with the great strength of the fingers, is specially adapted to its peculiar mode of progression, and not to the elevated uses which the human hand performs.

[1] Contributions to the Comparative Myology of the Chimpanzee, Boston Journal of Natural History, vol. vii.

In short, looking merely at man's body, beside being cosmopolitan and typically omnivorous, although it has a position and mode of locomotion peculiar to itself, and in which it certainly is unrivalled, it is also endowed with the power to assume with grace almost every conceivable attitude, and to employ at will the typical modes of locomotion of other Vertebrates, such as swimming, crawling, leaping, and climbing; and all these the human mind has found means to outstrip in point of speed; even the flying of the bird, though probably it can never be equalled in rapidity, has been imitated by the aërial mode of locomotion contrived by the same continent of man's essential superiority.

But, leaving the mind wholly out of view, the human body is so constituted as not only to best execute its own peculiar movements, but also to assume more readily than the brutes some which are peculiar to other species. In other words, while endowed with sufficient strength and firmness for all ordinary occasions, it has at the same time such flexibility and independence of action as to be able to apply this strength in many and very diverse ways.

For clearer illustration let us contrast two extremes, the arm of man with the fore-leg of the horse. The former can do nearly anything and everything except that of which alone the latter is capable, namely, to support and propel the body on the earth; yet in the two limbs are the same joints, and, except in the hand, the same bones and muscles; but in the quadruped the latter are short and thick, and so disposed on the front and back of the limb as to pull it with great force in those two directions, and in no other; while in man they are arranged evenly around the bony shafts, thus adding to the symmetry of the limb, as well as increasing its mobility.

But the most striking difference is, that, while the movements of each segment of the human arm are, if necessary, entirely independent of those of the other segments, in the horse they are much less so, and flexion or extension at the elbow causes a mechanical movement at the wrist, and *vice versa:* the independence of the movements of these two joints seems to correspond with the degree of development of the humeral condyles; these processes, when they exist, are situated just above the insertions of the external and internal lateral ligaments of the elbow, at which two points there is of course no motion; the condyles lie a little above and therefore change position, though very slightly, during movement at the joint. The extensor muscles of the wrist and fingers arise from the external condyle, the flexors from the internal, both processes being very prominent in man; but it is evident that when the condyles are very small or absent, the origins of the muscles must in like degree reach above or below the centres of motion, and thus, with the parts into which they are inserted, be more or less affected by any movements at the joint. Now in the horse the condyles are almost wholly wanting, the flexors of the hand arising below the centre of motion on the inner side of the humerus, and the extensors above the corresponding point on the outer side; when, therefore, the hand is flexed, the humerus and fore-arm are also flexed at the elbow, and when the hand is extended, these other segments are also extended.

Hold the fore-leg of a horse horizontally by the part between the elbow and wrist, and flex the hand; the limb bends at the elbow also. Now if you rest the limb in its natural position upon the earth, the obliquity in the direction of the hoof tends to extend the hand at the wrist, and thus to straighten the limb at the elbow, so that the heavier you press upon the top of the humerus, the firmer the limb becomes. It is evident that this would be a mechanical aid in sustaining the weight of the animal, but I have had no opportunity to look for a similar arrangement in the posterior extremity. On account of this same structure, however, the fore-leg gives way suddenly and completely when the animal stumbles so as to bear upon the tip of the hoof and so flex the hand at the wrist, for that brings the humerus down with it. In the hind-leg of the frog, which is used for little else than leaping, there is a somewhat similar arrangement, the great extensor of the foot being connected with that of the leg by a strong tendinous band on the inner side of the knee, so that extension of one segment is mechanically connected with that of the other. In the quadrumana and carnivora the condyles are present, though less prominent than in man; and indeed the degree of their development seems to correspond nearly with that of the clavicle, both of them being concerned in the freedom and mobility of the anterior extremity.

The new relations of morphology observed among the muscles of the mammalian limbs are intimately connected with two other generalizations applying to these parts; and these again are subordinate to the great anatomical law of "antero-posterior symmetry," as it has been hitherto called; and since little or nothing has been published concerning this in the form it has of late assumed, it may be well to state the law here, chiefly according to the views of Professor Jeffries Wyman, by whom it was suggested to me, and who, almost alone in this country, has devoted time to eliminating, from the indefinite and often extravagant and absurd shape in which it was left by Oken, the real truth of a principle the most potent and elevated of which the vertebrate body, considered by itself, is capable.

Yet in my opinion even this is subordinate to a still higher law which pertains as well to the other types of the animal kingdom, and also coincides with a geometrical law so closely as to afford new ground for its belief. In order to appreciate the full force and value of lesser laws, it must first be shown how they depend upon greater ones; and therefore the latter shall be first considered.

A partial statement of this higher law, which for reasons given further on I have called the *law of animal polarity*, was made by Professor Agassiz, at a meeting of the Boston Society of Natural History, December 4th, 1861.

He characterized the four leading types of the animal kingdom by four terms indicative of the general arrangement of their organs, or their plan of structure: the Radiates by "*radiality*," the Mollusks by "*laterality*," the Articulates by "*tergality*," and the Vertebrates by "*cephality*." In the Radiates all the parts are disposed about a common centre, encircling which also is the dynamic portion of the nervous system, a ganglion for each diverging segment or spheromere. These spheromeres are morphologically exact repetitions of each other, though their size and shape may be greatly modified, and even one of them may be entirely wanting, so that the animal appears as if divisible into two lateral halves, when really this is due to a teleological modification not at all affecting the real plan of structure, but only foreshadowing, as it were, the characteristic arrangement of the next higher type, just as the molluscan Bryozöa present an appearance of radiation in the disposition of their groups of tentacles. These two instances show the importance of always looking first at the more essential parts of the body, rather than at the outside, which, like other appearances, is often deceitful.

The *laterality* which Professor Agassiz considers characteristic of the Mollusks, must be carefully distinguished from the *bilaterality* or *bilateral symmetry* of all animals above Radiates: for the latter terms mean only that the body is composed of two lateral halves which are right and left repetitions of each other; and this is often more conspicuous in the Vertebrates, and especially in the Articulates with their sharply defined outlines, than in the almost amorphous forms of the Mollusca; but here again we must go beneath the surface, and then we find that in the Mollusks not only are the organs arranged upon the two sides of the body, but the "weight of organization," as Professor Agassiz expresses it, is thrown upon the sides, which even in common usage we recognize to have superior value over the front and hind ends, or the upper and lower edges; we examine and figure only the sides, and, except with the Cephalopoda, their natural position is such as to exhibit prominently one of the sides. This distinction between the *bilaterality* common to all above Radiates, and the *laterality* proper to the Mollusks, is well set forth by Mr. N. S. Shaler, in the Proceedings of the Boston Society of Natural History, December 4th, 1861.

With the type of Articulata, it is not the right and left sides that we chiefly regard in either a popular or a scientific examination, but the upper and lower regions, which are, as it were, set off against each other. We no more think of placing or viewing an insect on its side than a bivalve on its upper or lower edge, which correspond to the tergal and ventral regions of the Articulate. This seems to confirm the idea that the single ring representing the articulate unit is composed of an equal number of segments above and below a horizontally bisecting plane, and that the legs and wings when they exist are tergal and ventral repetitions of each other. But the internal anatomy is less satisfactory, at least as now understood, and I leave it to others, more familiar with its details, to determine whether this type, whose sharply defined outlines so clearly illustrate the law, has at the same time the most unsatisfactory internal arrangement; it is certain that in our present state of knowledge the laterality of the Mollusks is more apparent than either the tergality of the Articulates or the cephality of the Vertebrates.

This latter term, *cephality*, applied by Professor Agassiz to the highest type, indicates the extreme preponderance in function of one end of the body; which, at first on the same level with the other end, is gradually raised, till it attains the greatest possible elevation in the erect position of man. Professor Dana's term, "cephalization," is indicative of this gradual ennobling of one end of the vertebrate body, and, in man, of the devotion of the arms and hands to its requirements, a physiological return to an allegiance they always owed the head, to which, in fishes, they are actually attached.

In this connection it may be added, that, besides the overwhelming evidence adduced by Professor Owen in support of the view now generally received, that the scapular arch is really the modified pair of ribs of the posterior or occipital cranial vertebræ, there are other facts which indicate that in the early stages of even the higher Vertebrates, the shoulders and head are much nearer together than in their adult condition.

1st. The singular course of the inferior laryngeal nerve, whence comes its name of the *recurrent*, is inexplicable on any other than strictly morphological grounds; for, instead of proceeding by the shortest and most direct route to the larynx from its origin on the pneumogastric, it always forms a loop around the subclavian artery on the right side and the arch of the aorta on the left, even in the giraffe, where its length is several times as many feet as it would be inches on the ground of teleology alone. An account of a case of malformation, which first drew attention to this peculiarity, was published in the "Edinburgh Medical and Surgical Journal," for 1823, and the same Journal for the month of April, 1826, contains an account of a similar case, with an explanation of this apparent waste of nervous matter. Both of these accounts are quoted on page 379 of "Power's Surgical Anatomy of the Arteries."

2d. Professor Vrolik, in his work on Monstrosities, "Tabulæ ad illustrandam Embryogenesin Hominis et Mammalium," figures, and briefly describes, the skeleton of an anencephalous monster, in which one arm appears attached to the base of the skull, as if by arrest of development, while the other is in its normal position on the side of the thorax. With a view to ascertain whether, at any period, the shoulders of the mammalian fœtus are in actual contact with the cranium, I made careful examination of large numbers of fœtal pigs, and in the very smallest, just when the limbs begin to protrude from the sides as little fleshy buds, it is always at some distance from the head; so that, in the Mammalia at least, the fact of actual contact must be regarded as doubtful.

3d. But in most fishes they are firmly attached to the cranium, and in the tadpoles of the bull-frog (*Rana pipiens*) I have found the scapula closely connected with the posterior part of the cranium, either by muscle or ligament, which elongates as development proceeds.

Now the three terms, *laterality*, *tergality*, and *cephality*, are more or less complete expressions of the arrangement of organs at the *two poles* of the *three axes* of a *sphere*, the *lateral*, the *vertical*, and the *longitudinal*, one of which is specially prominent in each of the higher types, Mollusks, Articulates, and Vertebrates, while the Radiates are represented by the simple sphere itself, with no one axis more prominent than another; since the members of this type are not geometrical figures, but organic, living beings, they must have a structural axis around which their diverging segments or spheromeres are arranged; but this assumes such a variety of directions, being reversed between the Polyps and the Acalephs with most Echinoderms, and becoming horizontal in the Holothurians, as to entirely negative the idea of its having any such morphological significance as the axes of the other three types. These three are the main axes of a sphere, the only ones possible at right angles with each other; and they also correspond with the three dimensions of a solid, — breadth, thickness, and length, — while the sphere may be regarded as having no dimension, yet as capable of all. (See also Professor Agassiz's "Contributions to Natural History of the United States," vol. iii. chap. ii. sect. iv. on Morphology and Nomenclature, p. 76.) This gives us four plans, four *morphs* on which the animal kingdom is built, and this coincides with the number now believed to exist.

A strong corroboration from a different source is contained in the views of Professor Arnold Guyot, expressed in a course of lectures delivered during the winter of 1862, at the Smithsonian Institution, on the "Unity of Plan in Animals and Plants."

He presented, as an indication of the existence of no more nor less than four grand divisions among animals, the idea that the four types represent the four grand epochs in the life of a single animal; the Radiates are the starting-point, the germ, the simple cell, with life, but this of a low, indeterminate character, and inhabiting the water, the lowest medium; then comes a partial progress in one direction, with the development of the nutritive systems of organs, and this second stage is represented by the Mollusks, with their heavy bodies, devoted to digestion and circulation, and confined to the earth; then comes a partial progress in the opposite direction, with the development of the respiratory and motory apparatus, and this is well represented by the Articulates, chiefly inhabiting the air; and, finally, in the Vertebrates is typified the animal in its perfect state, with a more equal combination of both classes of functions.

Again, for the existence of four classes in the Vertebrates the same reason holds good: the Fishes are the starting-point, and, like the Radiates, dwell in the water; then come the Reptiles, with their heavy bodies attached to the earth, and characterized by special prominence of the nutritive functions, thus corresponding to the Mollusks; then the Birds, the aërial Vertebrates, their very bones filled with the medium in which they dwell, and always in active motion; and the cycle is again completed by the Mammals, which embody a more equal and harmonious combination of all the systems of organs, living, like the Reptiles, on the earth, but elevated above it into the free space of air.

Professor Guyot considered the same law to prevail throughout all the lesser groups of Mammalia, and also in the three other types; and it is certainly worthy of remark, that in these latter are recognized only *three* subdivisions, while in the Vertebrates *four* are generally acknowledged; and so in every group containing man would be four lesser groups, but in all others only three, the highest being wanting, and the series thus incomplete.

In this connection *circle* seems as proper as *series;* for the most natural exhibition of the relative standing of the four types is by four equidistant points on the circumference of a circle, the Radiates below, the Mollusks above and to the left, the Articulates the same distance above and to the right, and the Vertebrates at the top; the two intermediate groups, the types of partial progress, being at the same distance from the lowest and highest, and thus of equal rank, though opposite nature. Nor can we overlook the fact that there are four regions of the body, pelvis, abdomen, thorax, and head; and that, as I think Oken has said, Fishes are *pelvic* animals, Reptiles *abdominal*, Birds *thoracic*, and Vertebrates *cephalic;* and that neither Radiates nor Mollusks nor Articulates possess a distinct anterior segment containing any such overruling portions of the nervous system as does the head of the Vertebrates.

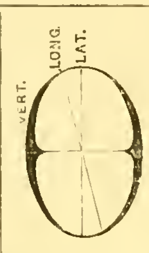
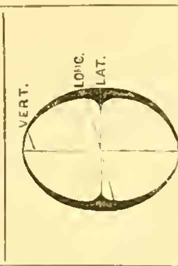
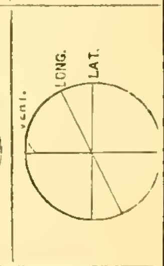
There are four senses also, one general, the others special.

The sense of touch is universal, and only more or less developed in different regions of the body: it is most exquisitely perceived through the agency of water or moisture, especially in the tongue; for taste is a peculiar exaltation of the general sensibility, and forms, as it were, a transition therefrom to the smell, one of the three special senses with which, as anatomy clearly shows, it cannot be allied. Of these latter, smell is the lowest, and its exercise depends upon the presence of odoriferous particles of an earthy, solid nature. Hearing is the second special sense, and perceives vibrations in the atmosphere, the next higher medium; while sight, the highest, depends for the exercise of its functions, not upon this, but upon that invisible and imponderable yet material medium which is called *ether*.

Again, *sight* is directly related to the central nervous system, and properly belongs to the *head*, below which its organ does not extend. *Hearing* goes lower down, into the *pharynx*, with which its organ is connected, anatomically by the Eustachian tube and physiologically when we listen to the speech of another. *Smell* and its accessory *taste* preside over the entrance to the alimentary canal, with which they descend through the head and thorax into the *abdomen*. Finally, in the *pelvis* is the organ which, as will be hereafter shown, is the posterior or reversed repetition of the tongue, and whose sensitiveness, like taste, is only a peculiar exaltation of the universal sense, the nerves in both cases being the common cranial or spinal nerves, and not special prolongations of the brain into the organ, as with the eye, the ear, and the nose.

Professor James D. Dana, in a paper "On the higher Subdivisions in the Classification of Mammalia," (American Journal of Science and Arts, vol. xxxv. January, 1863,) proposes a similar quaternary division of that class with special reference to the "cephalization" of the body, which he shows to increase as we ascend in the scale.

To those who make classification their study it belongs to decide how much influence these principles exert among the lower groups; but certainly among the higher ones the coincidences are too striking to be disregarded by the most matter-of-fact philosopher. I subjoin a diagram exhibiting the more evident correspondences in the various departments

Geometrical.	Morphological.		Zoölogical.					Physical.	Physiological.			
Dimension.	Prominent Axis.	Characteristic polarity.	Types.	Classes of				Element.	Region.	Sense.	Function.	State.
				Radiates.	Mollusks.	Articulates.	Vertebrates.					
Length.		Longitudinality.	Vertebrata.	The highest subdivision is wanting because Man is not included.			Mammals.	Ether.	Head.	Sight.	Intellectual.	Thought.
Height.		Verticality.	Articulata.	Echinoderms.	Cephalopods.	Insects. (Imago.)	Birds.	Air.	Thorax.	Hearing.	Motive.	Action.
Width.		Laterality.	Mollusca.	Acalephs.	Gasteropods.	Crustaceans. (Pupa.)	Reptiles.	Earth.	Abdomen.	Smell.	Nutritive.	Growth.
Spherical.		Radiality.	Radiata.	Polyps.	Acephala.	Worms. (Larva.)	Fishes.	Water.	Pelvis.	Touch.	Generative.	Germination.

of Nature, and which seem to indicate that here is one and the same thought of the Creator expressed in terms *geometrical*, *morphological*, *physiological*, and *zoölogical*.

From what has been said concerning the axes of the three higher types, it will appear that they all exist in each of the types, just as they would in a geometrical sphere, variously compressed; but that this *presence* of *all* must be carefully distinguished from the *prominence* of *one* axis in the type characterized thereby. Thus the *laterality* of Mollusks is something more than the *bilaterality* or *bilateral symmetry* which exists also in the Articulates and Vertebrates; the *cephality*, or more properly the *longitudinality* of the latter type must be distinguished from the *antero-posterior symmetry* so evident in certain Articulates; and the *tergality*, or more properly *verticality* of these, from any resemblance, if it should be observed, between the dorsal and ventral regions of the Mollusca; even the *radiality* of the lowest type must not be confounded with the *appearance* of it in certain Mollusks above mentioned.

But, in fact, mere *resemblance* between any two regions of the body is not what we desire to express; for, although it may exist, there is quite as often a striking contrast, as in the Gasteropoda among Mollusks, and in Man with most Mammalia among Vertebrates. Our term should refer rather to the direction of the axis which is specially prominent in any one type, at the poles of which are the two regions which are the external evidence of this prominence, and which morphologically repeat each other, but as has been instanced, may be teleologically most diverse; and therefore if *radiality* and *laterality* are accepted for the two lower types, (for despite our morphological equality of Mollusks and Articulates, the latter are physiologically the higher of the two,) the corresponding terms for the other types are *verticality* and *longitudinality*: for *tergality* and *cephality* only express the prominence of the region at *one* end of the axis over that at the other, a prominence which is teleological, while our idea is strictly morphological. Radiality, laterality, verticality, and longitudinality are, morphologically, peculiar to and characteristic of Radiates, Mollusks, Articulates, and Vertebrates respectively, but, teleologically, they may be as it were ingrafted upon the others in the shape of radiation, bilaterality, tergality, and antero-posterior symmetry.

In accordance with the law of polarity, we shall expect to find the organs at the two poles of a prominent axis morphologically similar, and thus to observe relations of polar homology between them,—of lateral homology in the Mollusks, of vertical homology in the Articulates, and of longitudinal homology in the Vertebrates; all existing more or less in each of these three, but specially prominent one in each; while in the Radiates there is the radial homology so early recognized between the four or five diverging segments. These four kinds of polar homology are the most general.

We come now to consider more particularly that relation of homology which is characteristic of the Vertebrates, and included in the idea of longitudinality, otherwise expressed by the compound term antero-posterior symmetry; both these terms are objectionable on the score of length, but the former is really significative of the idea we mean to convey.

It may be well at this point to find how fully our deductions are borne out by the facts.

It is fortunate indeed when our views *a priori* are confirmed by our investigations *a posteriori*, so that we safely ascend and descend the hill of science, without being dazzled and led astray by glittering and apparently correct generalizations, or losing our way amidst the labyrinth of facts, and, in our eagerness to advance, in place of steadily looking for the landmarks Nature has provided, becoming impatient and exhausting our strength in cutting down or rooting up, if possible to destroy, whatever stands in our way, or perhaps using it to bridge over gaps in our self-made path which never would have existed, if, at the outset, our aim had been to discover, not to create, to learn from God, not to be teachers ourselves.

If the previous reasoning is correct, it follows that the anterior and posterior regions of the vertebrate body, consequently of our own, are anterior and posterior repetitions of each other, but in opposite directions, like the right and left sides.

At first sight, nothing is more improbable to our thought or revolting to our feelings, and the evidence must be strong to overcome this natural repugnance to the relationship.

Yet why should it be objectionable, any more than that neither anatomy nor microscopy nor chemistry can detect the slightest difference between two human brains to indicate that one of them was the agent of a wicked and depraved, the other of a noble and lofty soul? It is the universal distinction between morphology and teleology, between the thing as it is made and as it is used; and when this distinction is once rightly appreciated, we shall be no more shocked at the morphological identity of the two ends of our corporeal frame than we are, or ought to be, at the close anatomical relationship between the disgusting ape and ourselves, remembering in both cases that it is the use alone which can ennoble or debase.

Our evidence is as yet by no means complete as regards all the organs of the vertebrate body, but enough has been brought out to very strongly confirm the principle.

As was implied when treating of the general law of polarity, we must, if this is acknowledged, recognize a new relation of homology between parts representing each other at the two ends of the longitudinal axis, and, in fact, on opposite sides of the longitudinal centre, similar to, but by no means so obvious as, that existing between the right and left sides.

This is not the "serial homology," of Professor Owen, for he regarded all the vertebræ and their appendages as simple repetitions of each other from one end of the body to the other, without recognizing the fact, which we shall see most clearly in the limbs, that the anterior and posterior organs of the body are repetitions of each other, but in *opposite* directions; so that the term "homotype," by which he designated parts serially homologous, really applies only to such as repeat each other on one and the same side of the longitudinal centre, and for the new relation between parts on opposite sides of this point a new term must be found.

Adopting the phraseology of Professor Owen we may call all parts which repeat each other as opposite ends of any axis "antitypes," and the antitypes of the lateral axis "latitypes," of the vertical axis "vertitypes," and of the longitudinal axis "longitypes," which will be specially characteristic of the three higher sub-kingdoms, Mollusks, Articulates, and Vertebrates, respectively, while the homologous diverging segments of the Radiata may be called "raditypes." In the Vertebrates the head and pelvis are longitypes; and the thorax and abdomen bear the same relation. This is a very general homology.

There will now arise, with reference to the longitypes, or the homologous parts in the anterior and posterior regions of one animal, a question similar to that concerning corresponding parts in two different species; which was whether they can be to the same extent homologous in animals bearing different degrees of zoölogical relationship: for example, the anterior extremities of all Vertebrates are homologous; but surely the arm of the monkey is more closely related to the fore-leg of the cat than either is to the flipper of the porpoise or the pectoral fin of the fish; and now, since the main axis or vertebral column begins to be formed at what is afterward the point of division between the fore and hind regions of the body, and the head and pelvis are situated at or near the ends of that axis, it does not seem possible that these parts can be as strictly homologous in animals having a different number of vertebræ as in those with the same number: in other words, the heads or the pelves of two animals may be cranial or pelvic modifications of vertebræ without being such modifications of the same identical vertebræ.

We have seen above that the vertebrate body is composed of four regions — head, thorax, abdomen, and pelvis. The tail is a pelvic prolongation, and not a distinct region, for though in the lowest class it constitutes so large a part of the whole body, and is the chief agent in locomotion, yet it contains no viscera, becomes more and more abbreviated, and at last disappears as we ascend, or, according to Prof. Dana, as the vertebrates become "cephalized." The number four at once furnishes a basis for a twofold longitudinal division, the head and thorax in front, the abdomen and pelvis behind; the head and pelvis are the extreme, and the thorax and abdomen the intermediate, antero-posterior representatives or antitypes of each other. Superficially or physiologically, the thorax seems better to repeat the pelvis; but this is due to the fact that in most vertebrates the anterior extremities are shifted back upon the sides of the thorax: which, of course, cannot be of importance in a morphological point of view; so that, so far as the limbs are concerned, and we shall find in them the law of longitudinality beautifully carried out, the head is more clearly shown to be the anterior representative of the pelvis. It is, of course, assumed that the vertebral theory of the skull is true, and that it also applies to the other or caudal extremity of the vertebral column, where the physiological degradation is usually as great as is the elevation anteriorly; with the difference that the tendency to linear multiplication is usually limited to four cranial vertebræ, while the tail may vary greatly in the number of its aborted vertebral segments. The four regions of the body are associated physiologically also in the same way: the two extremes are regions of *relation;* their functions, sexual and mental, are exercised with direct reference to other individuals, and the latter is capable of elevation to the highest communion possible between the finite and the infinite. But the functions of the two intermediate regions are of a *personal* and *selfish* nature, those of the abdomen being concerned in the support of the life of the individual within *itself*, and those of the thorax evolving the power necessary for motion and for influence upon the *world*.

The question next arises, Where is the longitudinal centre of the body? This cannot be indicated precisely, and perhaps varies in different species, but it undoubtedly lies between the two intermediate regions, thorax and abdomen, perhaps at that vertebra whose spinous process is upright, inclining neither backward like those of the dorsal, nor forward like those of the lumbar vertebræ; but this point will seem to shift its position according to the various physiological requirements as to the length of the thorax or abdomen, or the strength and mobility of the extremities.

Questions of morphology are often determined by embryology; — by reference to the early stages of development before teleological modifications have been superadded; the development of the vertebral column and of the enclosed myelon, conclusively shows that the morphological centre of the body is at the middle of the back, notwithstanding the cephalic end afterward acquires such physiological superiority. Ossification of the vertebral column commences at the middle of its length, and proceeds forward and backward from this point: the size of the bodies, or *centra*, of the vertebræ at this early period, diminishes anteriorly and posteriorly, and only later becomes more equal, which latter proportion persists through life in the lower mammalia but in the quadrumana and especially in man the posterior centra become thicker and stronger, so as to give the column that slender pyramidal shape necessary for the preservation of their more or less erect position, while the upper or neural arch is anteriorly expanded to accommodate the enormously enlarged cerebral ganglia, the long axis of which forms a decided angle with that of the cord.

Perhaps nowhere is the distinction between morphology and teleology more evident than in the cerebro-spinal axis. At the first appearance of this in the embryo, there is no such marked preponderance of the anterior portion as in the later periods, but the two ends present a nearly similar appearance, which similarity is persistent in the lowest fishes. There seems to be no good reason for regarding the anterior enlargement of the myelon as essentially or morphologically distinct from the posterior. The brain is an after-growth, for teleological cause, and the posterior enlargement is distinct, and, though entirely overbalanced by the immense development of the organs of the mind and special senses, is of no small importance even physiologically. No one who has suffered the excruciating pain in the small of the back, accompanying most febrile diseases, will question the importance of the portion of the myelon there situated, to which part also are referred the sensations of relief, more or less distinctly felt, upon the discharge of the contents of intestine, bladder, uterus or testis.

To avoid misconception, it may here be stated that from this morphological point of view, I consider the brain proper as a purely physiological addition with no posterior representative, and the so-called anterior and posterior enlargements of the spinal cord as bundles of the fibrous, that is, connecting or adynamic nervous substance, increased in size and number; but the medulla-oblongata as the true anterior morphological enlargement, the posterior representative or longitype of which is that apparently insignificant portion of the cord which lies behind the origins of the great lumbar nerves, but which contains a very large proportion of the gray or cellular or dynamic nervous matter.

But this point, and many others, demand investigations more rigid, minute, and even microscopic, and with reference to the principle involved. The idea of antero-posterior symmetry is as yet illustrated to us only by such parts and organs as conform to it more obviously by teleological likeness or unlikeness in the two regions of the body; and, though there is already enough to establish beyond a doubt, to my mind at least, the truth of this subdivision of the higher law of polarity, yet there is needed more time and labor than any one has yet been able to bestow, to demonstrate the more obscure relations of those parts which are only *morphologically* anterior and posterior repetitions of each other.

It is by no means unlikely that further investigations, broad and impartial, may show that, except between certain organs, the relation of polar homology is a *general* and not a *special* one; at any rate, I think we are not yet prepared to state what bones of the head and pelvis are longitypes; if mere consolidation and organic connection of the more anterior vertebræ constitutes the cranium, then many fishes have five or six, or even more cranial vertebræ, while in the frog the occipital segment is so divided that the two lateral elements, or *neurapophyses*, are separated from the *centrum* and *neural spine*, and so appear to constitute a distinct vertebra.

Perhaps the two or even the three anterior cranial vertebræ, the nasal, frontal, and parietal, are, like the special senses, not represented posteriorly. It may be said in favor of this view, that, while the universal sense of touch is perfected in the hands, which are the distal ends of the diverging appendages of the lower or hæmal arch of the posterior or occipital cranial vertebra, and taste, the modification of this universal sense, is located in the tongue which is supported by the hæmal arch of the next or parietal vertebra, the organs of the three special senses are located in or between the superior or neural arches of this and the two remaining segments, which indeed seem to exist only with reference to these and to the brain proper, none of which have posterior representatives; therefore, we might not expect to find in the pelvis any parts corresponding exactly to these special developments, but only the entire vertebra whose hæmal arch has for its diverging appendages the posterior extremities, with that portion, hæmapophysial, of the succeeding hæmal arch which supports the penis, the longitype of the tongue, the pleurapophysial elements of the arch being deficient.

In most mammalia, but by no means in all vertebrates, the pubic bones support the male organ of generation; the ischiatic bones are certainly the posterior of the two pelvic arches, and may reasonably be supposed to represent the hyoid bone ; at any rate, despite the vast teleological discrepancy, the anterior portion of the head seems, so far as morphology is concerned, to be the fixed longitype of the more or less movable series of vertebræ behind the fixed pelvis.

Having thus admitted a general homology between these two extreme regions of the body, we must wait for further evidence to show first, whether there is really any such special homology as at first appears probable, and if so, whether the clavicle and coracoid represent the ischium and pubis respectively, as the bones alone would indicate, or whether, regarding also the fleshy parts, the hyoid bone is the antitype of the ischium, and the clavicle that of the pubis, the coracoid being merely a process like the marsupial bone of the mammals characterized thereby.

The alimentary canal with its appendages next merits our attention.

The former is embryologically and morphologically a simple straight tube, with an anterior opening in the head and a posterior one in the pelvis. In the adult state, however, this tube is always more or less enlarged and convoluted, to afford a reservoir of the size, and an absorbent surface of the extent required by the nature of the food consumed; but all such modifications are purely teleological, and only conform to the general arrangement which assigns to the organs of nutrition a region below that in which are the organs of the motive forces, and above that devoted to generation.

There is at first but a single anterior and posterior opening, but the former is generally, and the latter in mammalia afterward, divided into a superior and an inferior opening; the nasal and oral, the anal and genital orifices, by transverse bands which bear the names of upper lip and perinæum.

With one exception, all sexual diversity is teleological, that is, resulting from a difference in the size or shape of parts which exist alike in both sexes. The exception is in the case of the ovary and the testis, which, being entirely distinct in every respect, constitute the only morphological difference between the two sexes; a true hermaphroditism is, of course, impossible, except between the two sides of the body; and this would be a positive condition, while all the so-called cases of hermaphroditism are merely negative and doubtful states.

In the anterior region, enumerating from above, that is, from the vertebral column downward, the parts are, the *nose*, or *anterior nares*, the *upper lip*, the *mouth*, the *tongue*, and the *chin;* posteriorly, the *anal opening*, the *perinæum*, the *vaginal opening*, the *penis* or the *clitoris*, and the *pubes*. The morphological correspondence is as evident as is the teleological difference.

There are two principal diverticula of the alimentary canal, the *lungs* and the *urinary bladder;* the former open forward and the latter opens backward, and their outlets are between the pharynx or mouth and the tongue, anteriorly, and between the vaginal opening and the clitoris posteriorly. There is a physiological relation also, for the bladder is a dilatation of the internal portion of the allantois, which was the fœtal organ of respiration. The thyroid gland is in relation with the larynx much as the prostate gland is with the neck of the bladder; but the former has no excretory duct as has the latter.

The heart, notwithstanding its lofty physiological preëminence, is, morphologically, only a more or less complicated enlargement and convolution of the great arterial trunk, just as the brain and stomach are teleological modifications of more simple fundamental parts; it and the stomach are examples of lateral displacement from their normal position as median organs. Terminating the vagina is the uterus, of which the longitype is not yet discovered; the mouth is the longitype of the vaginal opening into the alimentary canal, of which latter, however, it is the teleological inlet. Pathology seems to indicate that the testes and the parotid glands are longitudinally homologous; for inflammation of the former is very prone to invade the latter, by what is called metastasis, but which in this case may be a physiological indication of a morphological relation otherwise obscure. So, likewise, are connected the diseases and their remedies, of the genito-urinary and respiratory passages, and both these cases, with that of the irritation of the nostrils sympathetic with the presence of worms in the rectum, are simply analogous to what so often happens between parts which are laterally homologous. I am not aware that any disposition has yet been proposed of the other abdominal viscera, liver, spleen, pancreas, and kidneys; — and will merely refer to the view of J. Maclise concerning the two former, that they are laterally complementary, as stated on page 153 of his "Surgical Anatomy," where are also given several reasons for his opinion.

We come now to the limbs, of which there are, in vertebrates, two pairs: the one anterior, and the other posterior. Their general homology as diverging appendages of the hæmal arches of the occipital or posterior cranial, and of the anterior pelvic vertebræ, has been already indicated; and also the doubt as to the general and antitypical relations of the lower or hæmapophysial portions of those arches, supposed to be represented by the four bones, clavicle and coracoid, ischium and pubis. In many mammalia the two former exist only in the shape of processes from the scapula, which is the upper or pleurapophysial portion of the arch; this and its antitype the ilium, seem to follow the direction of the development of the vertebral column, the former pointing forward, and the latter backward. To the lower or distal ends of these elements, by the shoulder and hip joints, are articulated the proximal ends of the limbs proper; these are made up each of four segments; anteriorly, of the arm, fore-arm, hand, (wrist and palm,) and fingers; or, osteologically, of the humerus, ulna and radius, carpus and metacarpus, and phalanges; and posteriorly, of the thigh, leg foot, (ankle and instep,) and toes; or, of the femur, tibia and fibula, tarsus and metatarsus, and phalanges.

It is worthy of remark, that the number of component parts of the segments increases toward the distal ends, while their individual mobility is diminished in the same direction as if for mutual compensation, and in accordance with the general rule that the right of *discretion* increases and diminishes with *responsibility.*

Now the law of polarity is morphological; but in this case, the teleology also is very evident; the divergence of the scapula and ilium is on the principle of a pyramid, the base being wider than the top, so as to afford a firmer support; we shall find the same polarity carried out in the segments of the limbs themselves with one exception, the necessity of which is, however, as obvious as the grounds for the general arrangement therein departed from; and indeed throughout the limbs, which as a whole are teleological superadditions, the uses of the general laws are so apparent that the latter seem almost teleological, the two principles being, as it were, blended and thoroughly harmonious.

The general correspondence between the four segments of the anterior and posterior limbs is evident; the arm or humerus and the thigh or femur, the fore-arm and the leg, the hand and the foot, the fingers and the toes are easily seen to occupy similar positions in the limbs to which they belong; but the law of longitudinality is further carried out among these segments according to what may be called corollaries thereof.

1st. Two corresponding segments in the fore and hind limbs point, and are flexed or extended, in absolutely opposite though relatively similar directions.

2d. Two contiguous segments of the same limb also point, and are flexed or extended in opposite directions, so that the *flexor* muscles of one segment lie on the same side of the limb with the *extensors* of the segment next above or below, and *vice versa*.

All this is easily seen in the mounted skeleton of any quadruped; the scapula and ilium diverging, the humerus and femur converging, the fore-arm and leg again diverging, the foot pointing forward, and the toes, since their flexion is in the direction opposite to that of the foot at the ankle, really pointing backward; but their antitypes, the hand and fingers, seem to point also in the same instead of the opposite direction, so that two and even three sets of muscles, which by their contraction shorten the arm, lie upon one and the same side of the limb.

To understand this apparent anomaly, it must first be remembered that the entire limbs are teleological, and that the influence of morphology diminishes as we recede from the morphological centre toward the distal extremities; moreover, the functions of the hands are various to the highest degree, and they, as the special agents of the brain, may be supposed to partake somewhat of its independence of morphological restraints.

Embryology throws light on this point. In the early fœtal periods, the two bones of the fore-arm are parallel, and this alone is sufficient indication of their morphological relation in the course of development the hand is gradually pronated, so that the lower end of the radius, the outer bone, crosses the ulna, and so becomes internal, causing the palm to face downward and *backward*, instead of, downward and *forward*. In this relation, more or less firmly connected, the two bones remain in quadrupeds; for they, not being stationary geometrical figures, but organized living creatures intended to move from place to place, must be able to strike the earth alike with both pairs of limbs in order to propel the body in the opposite direction; but in monkeys and in man, where the anterior extremities are not merely for progression but for executing the higher mandates of the will, the radio-ulnar articulations remain free, and the parts may be restored to their normal condition by supinating the fore-arm, the palm still facing downward, but now also forward instead of backward; the fingers flex forward and the toes backward, although made to act as continuations of the larger segments, hand and foot.

Morphologically, the flexion of the hand at the wrist must be in a direction opposite to the flexion of the fore-arm at the elbow, and therefore the muscles which raise the so-called back of the hand toward the back of the fore-arm are really the *flexors* of the former segment, and correspond to the muscles which elevate the dorsum of the foot toward the front of the leg; and, *per contra*, the muscles which bend the palm of the hand toward the inside of the fore-arm, are really *extensors*, and correspond with those which in the posterior limb act upon the foot through the *tendo Achillis;* that is, the muscles now called *extensores carpi radialis* and *ulnaris*, are morphologically *flexors*, and their antagonists, now called *flexores carpi radialis* and *ulnaris*, are *extensors*, and will be so designated in this paper.

There are two apparent objections to the above interpretation of the antitypical relations between the fore and hind limbs, but as will be seen, they are only apparent, and against their entertainment may be urged all that has been, and much more that might be, said concerning the distinctions between morphology and teleology, and the fallacy of deductions from either respecting the other.

The first is, that by rotating back so as to leave the ulna and the radius parallel, the former must correspond to the inner bone of the leg, *tibia*, and the latter to the outer bone, *fibula*; yet the radius forms most of the wrist joint, and the tibia forms the ankle, and, as the power of rotation gradually disappears in the mammalian series, it is the ulna in the fore leg, and the fibula in the hind leg, which decreases in size through the carnivora, till in the permanently pronated fore-arm of the ruminants, solipeds, and some pachyderms, the ulna is represented only by the olecranon process and the upper half of the shaft soldered to the radius, while in the posterior limb scarce a trace of the fibula remains; in other words, the homologous bones of the two extremities are developed in an inverse instead of a direct ratio; but relations of *more* and *less*, like those of *form*, are always dependent upon function, and therefore not safe guides to homology, so that this cannot be taken as a real objection to the law of longitudinality, borne out as it is by the entire vertebrate structure wherever the original plan is retained or can be detected under its various teleological modifications. We may however connect this fact with another, so that it shall to us seem to have, what with all things in nature it certainly must have, a more or less remote foundation in use. As we have seen above, in a morphological point of view, the ulna is the inner, and the radius the outer, bone. This is the relation which they bear in the fœtus and which harmonizes best with other parts; but this admits of such variation that in nearly all mammals below the quadrumana, the radius becomes inner and the ulna outer. Now, for some cause not yet understood, it is best for both hand and foot in quadrupeds to be connected with the inner bone of the legs, and in provision for this the hand is in all the mammalia supported by the radius which in the four-footed members of the class is the inner bone.

The second and more obvious though equally fallacious objection is, that of the five digits which terminate the anterior and posterior extremities, the outer ones will then be the thumb and the little toe, and the inner ones the little finger and great toe. Perhaps no correspondence has been more generally admitted, and even taken as a basis for other investigations, than the analogy between the thumb and the great toe, not only because in the commonly accepted condition of the parts they both occur on the inner sides of the hand and foot, but because they are so constantly composed of *two* phalanges, while all the other digits possess *three*.

But even if it were true, which it is not, that this same numerical relation prevailed among the three other classes of the vertebrate sub-kingdom, and there were therefore some grounds for regarding as morphological a rule for which no sufficient teleological cause is yet apparent, we could not reasonably accord to any deviation at the very distal extremities of the limbs, a value sufficient to outweigh the teachings of all parts between them and the morphological centre of the body; and it is better to acknowledge our ignorance of the meaning of one fact than to purposely ignore the existence of others far more numerous and important.

I will here mention the comparisons between the anterior and posterior extremities of vertebrates which, since the time of Winslow, (1775,) have been made by many of the most celebrated anatomists, such as Vicq d'Azyr, Sœmmering, Goethe, Meckel, deBlainville, Barclay, Gerdy, Blandin, Bourgery and Cruveilhier, Turenne, Flourens, Owen, and more recently, Mons. Chas. Martins, Professor of Medical Natural History of the Faculty of Medicine of Montpellier, in a paper entitled, "Nouvelle comparaison des membres pelviens et thoraciques chez l'homme et chez les mammifères déduite de la torsion de l'humerus," (Annales des Sciences Naturelles, tome viii. p. 45, 1857.) And again in 1862, in a second paper entitled, "Memoire sur l'ostéologie comparée des articulations du coude et du genou chez les mammifères les oiseaux et les reptiles."

In the former, after discussing and objecting to the views of the other anatomists above named, he says on page 55: —

"To recapitulate, these comparisons (parallèles) of the superior and inferior extremities of vertebrates may be reduced to three:

1st. The hypothesis of Vicq d'Azyr, who compares the superior member of one side with the inferior member of the other side. (Plate ii, figs. 1 and 3.)

2d. The detailed (détaillé) comparison of Bourgery, who combines the hypothesis of Vicq d'Azyr, with a crossing, in virtue of which the head of the tibia represents the ulna, its lower extremity the radius, while the femoral extremity of the fibula corresponds with the radius, and its tarsal extremity with the ulna.

3d. The explanation of Flourens, where the pelvic member of one side is assimilated with the thoracic member of the same side, the *fore-arm being in a state of pronation*."

We may easily see, as Mons. Martins has shown, that each of these comparisons is open to serious objections, while their discordance is such that even at this late day those anatomists who do not utterly discredit the existence of any natural relation between the fore and hind limbs "are in doubt between them, without being able to agree upon the most important point, namely, the identification of the two bones of the fore-arm with those of the leg."

It will be noted that through all these comparisons runs the effort to demonstrate a *parallelism* between the anterior and posterior extremities, and not one of the anatomists who advocate them seems to have appreciated the significance of Oken's *a priori* assertion of an *oppositeness* or *symmetry* between the two ends of the vertebrate body, which generalization he simply did not extend to the limbs, the diverging appendages of these two regions.

That this *oppositeness* or *symmetry* does really exist, has I hope been already shown in this paper, and I desire to repeat here that the first suggestion of the idea to me came from my illustrious instructor in anatomy, the Hersey Professor of Anatomy in Harvard University, from whom, much rather than from myself, would I prefer that others should learn what has afforded me so much mental pleasure and profit.[1]

Mons. Martins' view is in his own words, as follows: "The humerus is a bone twisted on its axis 180 degrees. The femur is straight without twisting. The humerus being a twisted femur, if we would compare the two bones, we must first untwist the humerus."

In other words, having made up his mind that the limbs are *parallel*, and finding that they are *not parallel*, he makes them so by a process of untwisting, to which I hope, others will perceive obstacles both mental and physical.

[1] See a short communication by Professor J. Wyman to the Boston Society of Natural History for June 6th, 1860. Proceeding sof B. S. N. H., vol. vii., p. 317, "on anterior and posterior symmetry in the limbs of mammals."

He then goes on to say: "The anterior extremity having been thus untwisted, the radius and tibia (which he considers analogous bones), are on the inside, while the ulna and fibula are on the outside; also the thumb and great toe, and the little finger and little toe, are respectively inside and outside;" all which correspondences do of course confirm him in his preconceived idea; but since, as has been shown, they are only analogies, not homologies, they do not in the least affect the true view of the case. Anatomy should be studied from the centre outward, as well as from the circumference inward.

Under the head of "Evidence of the torsion of the humerus," Mons. Martins adduces the raised line which passes from the condyle across the front of the bone, and the general direction of the vessels and nerves of the upper arm; not perceiving that both are only physiological provisions, in the one case for the attachment of muscles, and not appearing till needed; and in the other for the better protection of the vessels and nerves, as is, moreover, equally the case in the lower limb. What can Mons. Martins think of the numerous ridges and apparent contortions presented by all the bones of the great ant-eater (Myrmecophaga jubata)? It would be difficult to determine how many degrees they should be untwisted to conform to his ideas of their normal condition. Unfortunately, Mons. Martins has not taken warning from his predecessors, and is, like them, haunted with the idea of parallelism, but his view has, in one respect at least, the merit of originality; for while they humbly took things as they found them, and patched them up as well as they could, he boldly declares that things are not what they seem, or at least seem not what they ought to be, and with his own hands sets them aright. His preëstablished theory is a very Procrustes' bed, to which facts must be adapted, whatever their real import.

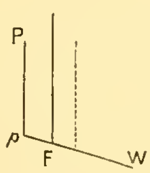
Having done this violence, however, his conscience reproaches him, and he thinks to appease outraged Nature by conceding what he is pleased to consider a "metaphysical difficulty," (p. 65.) Here, after admitting that *no such twisting ever takes place*, and that in youth, before the development of the muscles has raised lines on the bones, *no evidence of torsion exists*, he declares that "this torsion of the humerus is not *mechanical*, but only *virtual*, though producing the same effect as if it were real." Also that "natural history is full of such facts." The examples he adduces are undoubtedly such; but a sounder illustration is to be drawn from the position of the whole anterior extremity; this is now admitted by all to represent the pair of ribs with their diverging appendages of the occipital cranial vertebra, not only in fishes where the contact is actual, but also in all other vertebrates, man included, as stated above. But the reasons for this conclusion are very weighty, since in addition to the fact that the homologous parts in fishes are actually so attached, there else would be a vertebral segment minus a pair of ribs, and a pair of ribs minus a vertebra; nor indeed is it certain that even in the higher vertebrates the anterior extremity is not at some time in contact with the cranium, while the other evidence is absolutely conclusive as to the morphological relationship. So that we may say there is a positive necessity for so disposing of these otherwise vagrant vertebral elements. But no such necessity compels us to assume a torsion of the humerus in order to gain a clear and philosophical view of the vertebrate limbs; and even if in our opinion it did, no such torsion ever takes place, as is acknowledged by Mons. Martins; so instead of a metaphysical difficulty in the way of his supposed reasonable theory, we find serious, aye, insurmountable, difficulties opposed to a very metaphysical and visionary idea.

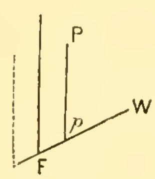
Two wrongs do not make a right, and when we are in doubt, it is better to follow Nature strictly and try to discover her way of reconciling apparent discrepancies, than to assume what is not the case in order to conform to a preëstablished theory.

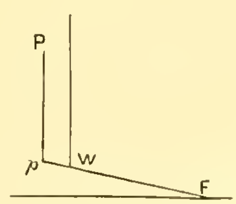
The mechanical conditions necessary for making use of muscular contractility are two points, one generally fixed and the other movable, to which the extremities of the muscle are attached, as in the face, where the muscles may arise from the bone and be inserted directly into the skin, or other part to be moved. In this way, of course, all the power of the muscle is utilized; but for the various requirements as to rapidity of action and beauty of proportion, a part of the power is more often sacrificed by the introduction of two other points,— one fixed, the fulcrum, and one movable, like the part to be moved, but nearer to or farther from the fulcrum, and into which now the muscle is inserted.

This is the more usual method of applying muscular contraction, and converts the various segments of a limb into levers, which are so far strictly mechanical. Thus, in flexion of the fore-arm, the *biceps*, and *brachialis anticus* do not reach directly from their origins on the scapula and humerus to the hand, which is the part to be moved, but two other points are introduced,— one fixed as a fulcrum, the elbow-joint, the other movable at the insertion of the muscles on the fore-arm, thus between the fulcrum and the part to be moved, which represents the weight.

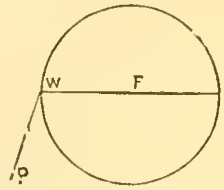
Levers are of three kinds. The first is where the fulcrum lies between the power and the weight; of this kind are all segments of the limbs when acted upon by *extensor* muscles. The third kind is where the power is applied between the fulcrum and the weight, and to this class belong the same segments when acted upon by *flexor* muscles. The second kind of lever is where the weight lies between the power and the fulcrum; of this there are no examples in the body acting by and upon itself, but whenever extension of a limb is employed for raising or supporting the body from the earth, then the different segments from levers of the first become levers of the second kind. Thus, in rising on tiptoe, the weight of the body rests upon the ankle, and so between the ball of the foot, which, resting on the earth, forms the fulcrum, and the heel, to which by the tendo Achillis is applied the power of the *gastrocnemius* and *soleus* muscles. I subjoin line illustrations of these three kinds of levers.

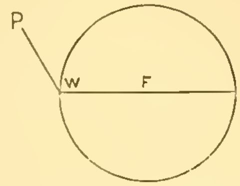






Adduction and abduction are only lateral flexion and extension; circumduction is a compound movement resulting from gradual and successive direct and lateral flexion and extension; even rotation is essentially a peculiar form of the same two movements, for the power is applied at the periphery of the rotated bone or limb, and so at one end of an imaginary diameter line through the centre, which latter represents the fulcrum; the weight may be regarded either as suspended from the half of the line or lever *furthest* from the power, in which case the diameter line would be a lever of the first kind, or as sustained upon the *nearer* half and thus between the power and the fulcrum, when it would be a lever of the second kind.





Of course, any obliquity in the direction of the muscle or bone, or any variation in the shape of the rotated bone or limb, or the presence of any part as the hand, which may be appended to the extremity, will only appear to complicate the motion without essentially affecting its character.

The general law, according to which the muscles of the mammalian limb seem to be arranged, is in no way startling or peculiar, and the only wonder is that it has never been observed before. No new facts are required for its illustration; human anatomy contains the great bulk of the material, though of course aided by comparative anatomy; and it needs only to see that the facts are not arbitrary, but bear such mutual relation as clearly to admit of one general statement. I will commence with the muscles which act upon the fore-arm, that segment of the anterior extremity in which I first detected the arrangement, and in which it is quite closely adhered to.

There are two *direct* flexor muscles of the fore-arm: one is the *biceps* arising from the scapula and inserted into the radius, the other is the *brachialis anticus* arising from the humerus and inserted into the ulna, though both, of course, are attached to one and the same segment, fore-arm. But this segment may be also flexed *indirectly* by the ulnar and radial extensors of the wrist; for when a joint is partially or wholly fixed by the simultaneous contraction of antagonist muscles on opposite sides, then the two segments between which the joint intervenes become teleologically as one segment, which is acted upon by all muscles arising from any other segment, and inserted into either of them; each segment being acted upon *directly* by the muscles which are attached to itself, and *indirectly* by those attached to the other. The fore-arm is directly extended by two muscles, one short, the *humeral heads* of the *triceps*, and the other long, the *scapular head* of the same; the indirect extensors are the ulnar and radial flexors of the wrist, commonly called *extensores carpi ulnaris* and *radialis*.

The humerus is flexed upon the scapula by three muscles, — *directly* by two, one short, *teres major*, arising from the scapula, and one long, arising upon the side of the body, *latissimus dorsi*; and indirectly by the third, the scapular head of the *triceps* which is also the long direct extensor of the segment next below.

How is it now with the corresponding segments of the posterior extremity? The leg is flexed at the knee, directly by two sets of muscles, one of which is represented by the *poplitæus* with the short head of the *biceps* when it exists, the former corresponding with the short direct flexor of the fore-arm, *brachialis anticus*; the other set is composed of the long head of the *biceps* with its accessories, the *semi-tendinosus* and *semi-membranosus*, the former corresponding with the long direct flexor of the fore-arm, *biceps humeri*; while the *peronæus longus* and *tibialis posticus*, with their accessories; the muscles composing the calf of the leg, and which are long direct extensors of the foot, are, if the ankle-joint is fixed, the indirect flexors of the leg, the segment next above, and correspond thus with the *extensores carpi* and the *palmaris* in the other extremity.

Here are enough examples to illustrate the general rule which may be stated in several ways, according as we specially regard the muscles themselves, or the bones; and these as segments of *insertion* acted upon, or as segments of *origin* from which the muscles act.

The muscles of the limbs form two groups, *long* and *short*; the short muscles arising from the *first* segment above that into which they are inserted, and the long from the *second* segment above. A short muscle can act in but one way, but a long one has two actions: one *direct* upon the segment into which it is inserted, the other *indirect* upon the segment which intervenes between its origin and insertion.

Each segment of a limb is flexed or extended by three muscles or groups of muscles; of these, two are inserted into itself, and are therefore called *direct* muscles, flexors or extensors; one arising from the segment next above the segment to be moved, and hence called the *short* direct, and the other arising from the second segment above, and hence called the *long* direct; the third muscle is termed the *indirect* flexor or extensor, and is the *long direct extensor* or *flexor* respectively of the next segment below, and between whose origin and insertion intervenes the segment under consideration.

Or it may be stated in yet a third way, using the humerus as an example. Each segment not only gives *insertion* to the four muscles which act upon itself, short and long extensors, *deltoid* and *pectoralis major*, and flexors, *teres major* and *latissimus dorsi*, but also affords *origin* to four more, of which two are the short flexor and extensor of the segment next below, *brachialis anticus* and *humeral* heads of *triceps*, and two, the long extensor and flexor of the second segment below, *extensor* and *flexor carpi radialis*, which are also the indirect extensor and flexor, respectively, of the first segment below.

There are several advantages apparent in this arrangement of the muscles of the limbs, and probably many more than have yet occurred to me. The most comprehensive is, that while one half of the muscles, the short, are able to execute but one movement, since but one joint intervenes between their origin and insertion, the other half may act in either of two ways, since two joints intervene between their origin and their insertion. Take for example the *biceps humeri*; its lower extremity is associated with the short flexor of the fore-arm, *brachialis anticus*, which is thus its *associate* of *insertion*, while its upper extremity is associated with the short extensor of the humerus, *deltoid*, which is thus its associate of *origin*; in like manner its *antagonist* of *origin* is the short flexor of the humerus, *teres major*, and its antagonist of *insertion*, the short extensor of the fore-arm, *humeral* heads of *triceps*. Now when the elbow, its joint of insertion, is fixed by the simultaneous contraction of its associate of insertion and its short antagonist of insertion, then the *biceps* can act only with the *deltoid*, its associate of *origin*; but when the shoulder, its joint of origin, is fixed by the simultaneous contraction of its associate of origin and short antagonist of origin, then the *biceps* acts with its associate of *insertion* to flex the fore-arm.

Here is the great advantage in having both long and short muscles; each long one may act in two ways, and the short ones are then required to counteract one of the actions while the other is performed. Moreover, it often, and in fact usually, happens, that two or more segments of a limb are to be flexed or extended together, and this is provided for by the same arrangement, with the additional fact that the short muscles are generally shorter and thicker than the long. Suppose that two contiguous segments, as arm and fore-arm, are to be extended at the same time. In this case neither of the short flexors, *teres major* and *brachialis anticus*, can act at all, but the long flexor of the lower segment, *biceps*, is enabled to act as the indirect extensor of the upper segment with its short associate of origin, *deltoid*, its flexor power being counteracted by its short antagonist of insertion, *humeral* heads of *triceps,* which, being more powerful, continues to act as an extensor, beside leaving the long extensor, *scapular* head of *triceps* entirely free ; the action of the latter, as an indirect flexor of the humerus, being in like manner more than counteracted by the short extensor of the same, *deltoid.* But if the same two segments are to be simultaneously flexed, then the short extensors do not act at all, while the extensor power of the long direct flexor, *biceps,* is overbalanced by its short antagonist of origin, *teres major,* and that of the long direct extensor, *scapular* head of *triceps,* by its short antagonist of insertion, *brachialis anticus,* leaving the two long flexors, *latissimus dorsi* and *biceps,* free as flexors of the two segments ; moreover, the long rotators of the fore-arm, *supinator longus* and *pronator teres,* with the long extensor of the wrist, *extensor carpi radialis,* and here by exception, even the long flexor of the third segment below, *flexor communis digitorum sublimis,* now act as indirect flexors of the fore-arm, their direct actions being, if necessary, prevented by their short antagonists, or in the case of the rotators by each other.

Again, as has perhaps been already inferred, the three muscles acting upon any one segment, are, potentially or *morphologically,* of the three degrees of length in *direct* ratio, but of thickness in *inverse* ratio ; and since the power of a muscle is in proportion to its thickness, and the distance through which it can contract, according to the length of its fibres, it follows that a movement is most rapid and forcible at the beginning, when all three muscles act together, and least so at its close when the longer and weaker muscles act alone ; and this agrees with the observations on the variation in the force of contraction of a single muscle, which is found to be most forcible at the beginning, least so at the end.

I have now stated the general law and the general advantages gained thereby as illustrated in those regions where the muscles are most familiar and where the law is quite closely adhered to, yet even here were some departures from it ; and in the remaining portions of the limbs will be found even more variations, according to the number and kind of movements required at the several joints.

There is considerable doubt with regard to the muscles acting upon the scapula, and for two principal reasons, one teleological and the other morphological ; for, beside the complication necessary for the very free movement upon the walls of the thorax, of a part which in many mammalia has no bony connection therewith, there is so much difficulty in comprehending the true relations of some muscles arising from the head and cervical vertebræ, and inserted into the scapula and clavicle, as to afford additional, though for the present vague, evidence concerning that remarkable change, by which the scapular arch has been displaced backward from the occipital cranial vertebra, of which it is in most fishes actually, and in all vertebrates morphologically, the pair of ribs.

The scapula slides upon the sides of the thorax, and is separated from it chiefly by muscles, having in most mammalia no bony connection with the rest of the skeleton ; and the muscles which act directly upon it, are, like those of the face, inserted at once into the part to be moved, without the additional mechanical complication of levers. It may be elevated and depressed, drawn forward toward the sternum, or backward toward the vertebral column. Two direct muscles draw the scapula forward ; one, the *pectoralis minor,* inserted into the coracoid process, the other, the *serratus magnus,* attached along the posterior border, both arising from the ribs ; two direct muscles also draw it backward, the *trapezius* outside, inserted upon the clavicle and spine of the scapula, and the *rhomboideus* inside, inserted into the posterior border, and both these arising from the vertebral column. Here then, as usual, are two flexors and two extensors, but as there is no part beyond the vertebral column or sternum on the middle line, all four are teleologically *short* muscles, since but one joint intervenes between their origins and insertions; it seems likely, however, that in a morphological point of view, the outer ones, *trapezius* and *pectoralis minor*, are the long muscles. The scapula is elevated and depressed *directly* by the oblique descending and ascending fibres of the muscles already described or *indirectly* by the long muscles of the humerus *pectoralis major* and *latissimus dorsi*. The true affinities of the *cleido-mastoid* and *levator claviculæ* have not yet been determined; the *omo-hyoid* is probably the representative of an intercostal muscle connecting the ribs of the occipital and parietal vertebræ; the *levator anguli scapulæ* is commonly regarded as a distinct muscle, but from some facts in its comparative anatomy, it appears to me rather as a dismemberment of the *serratus magnus*. All this is rather unsatisfactory, and will, I think, continue so till embryology and comparative anatomy have demonstrated the true relations of these muscles, and the extent to which they vary from the common type of the *intercostales;* for it must be remembered, that the scapula and its posterior representative, the ilium, are not, properly speaking, segments of the limbs, but the dorsal moities or *pleurapophyses* of modified ribs, at the junction of which with the ventral moities or *hæmapophyses*, are given off diverging appendages in the shape of the anterior and posterior extremities.

The *deltoid* is the short extensor of the humerus, arising, as it should, from the scapula; either the long extensor is wanting, or, as is more probable, it is represented by the *pectoralis major*, or one of the several subdivisions of the latter, existing in quadrupeds, where the clavicle is deficient. The long and short flexors of the arm, *latissimus dorsi* and *teres major*, have been already noticed. With regard to the *supra* and *infra spinati*, the *subscapularis* and *teres minor*, I am not yet decided; in man they are chiefly rotators of the limb at the shoulder, but in quadrupeds where the humerus is simply flexed or extended, the three former have more or less power of extension, while the *teres minor* is a flexor. The muscles acting upon the fore-arm have been already described; the *dorso-epitrochlien* of Duvernoy ("Des caracteres anatomiques des grands singes pseudo-anthropomorphes," Archives du Museum, vol. viii.) which exists in the quadrumana and most of the mammalia, has nearly the same relations as the *scapular head* of the *triceps*, being, when inserted upon the olecranon, a direct extensor of the fore-arm as well as an indirect flexor of the humerus, which alone it flexes directly when attached to the internal condyle.

The relations of the *biceps* in the higher mammalia are somewhat complicated by the provisions for rotation between the two bones of the fore-arm, converting that otherwise single segment of the limb into two, whose greater lengths are parallel with, instead of perpendicular to, the axis of motion at the radio-ulnar articulation; and since the *biceps* is attached to the radius, it really extends over three joints, and can act in three ways: at the shoulder in extension of the humerus, at the elbow in flexion of the fore-arm, and at the radio-ulnar articulation in supination or extension of the radius; for, regarding these two bones alone, supination is extension, and pronation is flexion.

It will be seen, however, that the radio-ulnar articulation is not a joint, in the same sense as is the shoulder or the elbow. These latter are constant or nearly so throughout the vertebrate series, and are important anatomical characters; they are strictly *morphological* joints; but the arrangement by which movement is permitted between the two bones of the single segment fore-arm, exists in comparatively few species of mammalia, and these such as in their approach to man, have their fundamental structure most modified in relation to the higher uses they are to perform. The radio-ulnar articulation is properly a *teleological* joint, and as might be expected, its existence does not really interfere with the general plan of the muscles any more than if the fore-arm were, in some one species, broken, and thus movable at the middle of its length, some of the muscles being inserted upon the proximal, and others upon the distal moiety. Moreover, the muscles specially connected with this joint, lie all upon the same side of the limb; namely, with the flexors of the fore-arm and the extensors of the hand, while, if it were a real joint, we should expect to find the supinators or extensors on the same side as the flexors of the fore-arm, and the pronators or flexors on the same side with the extensors of the hand; but in fact, as before stated, they all lie upon the same side; whereby the long supinator and pronator are both made to assist the flexion of the fore-arm, which is evidently of more importance than its extension. The radio-ulnar articulation is therefore a teleological interpolation, presenting none of the characters of a true joint between the real segments of a limb.

The two opposite movements of pronation and supination are performed by two sets of muscles; those of one set are short, the *pronator quadratus* and *supinator brevis*, arising from the ulna, the first segment above their insertion; those of the other set are long, the *pronator teres* and *supinator longus*, arising from the humerus or second segment above their insertion; and here, as with the muscles of the true joints, the short muscles have but one action, to move the radius or counteract each other; while the long ones either act directly in a similar manner or indirectly flex the fore-arm, the segment which, as to its fixed bone, the ulna, intervenes between their origins on the humerus and their insertions on the radius. The *biceps* is really the most powerful supinator of the radius, and can turn the palm of the hand completely upward; while the two supinatores can only bring the thumb or radial border of the hand uppermost. There are four muscles acting directly upon the hand, (carpus and metacarpus;) two flexors, radial and ulnar, and two extensors, radial and ulnar; the ulnar flexor and extensor arise chiefly from the bones of the fore-arm, and are the short muscles, since they come from the first segment above that to be moved, and the two radial are the long muscles arising from the humerus, the second segment above. The long, or radial extensor, is also the indirect flexor of the fore-arm, and perhaps, morphologically, the radial flexor is the indirect extensor of the same intermediate segment, though I am not aware that it ever is so actually; and on the contrary, when, as in the horse, the humeral condyles are wanting, the extensor arises on the *inner* side, *below* the centre of motion, and would thus act as an *extensor* of the fore-arm, while the flexor arises from the *outer* side *above* the centre of motion, and is therefore physiologically a *flexor* of the same segment.

If we regard the fingers as a single segment, then there is a short and a long flexor, *flexor communis sublimis* and *flexor communis profundus;* but these would then seem to arise each from one segment above what would be expected; the former from the humerus, and the latter from the fore-arm; but the *insertion* of a muscle is of more importance morphologically than its *origin*, which latter is in relation to the required length of the muscle and the proportion of parts, and therefore more liable to vary; so, taking the less modified foot for comparison, it seems more natural to suppose that the *flexor profundus* is, morphologically, the long flexor, and the *flexor sublimis* the short; its origin having been moved upward two segments on account of the very extensive movements required of the fingers, more extensive in proportion to their size than those of any other part of the body.

With this view, the short flexor of the fingers, like the short flexor and extensor of the toes, is inserted into the second phalanges. That the proper short palmar muscles of the thumb and little finger are not the true representatives of the short flexor is shown by their co-existence in the foot with an unmistakable short flexor. There is no long extensor of the fingers, unless the proper extensors of the first, second, and fifth digits are remaining portions of it; the only common extensor, like the superficial flexor, having been moved as to its origin, two segments above its normal position, like the short extensor.

In general, the muscles, like the bones of the posterior extremities, repeat in an opposite direction those of the anterior, but the exact correspondences between individual muscles are far more difficult to determine than would be expected, either from the apparently more simple functions of the limbs as such, or from the close antitypy exhibited by their osseous framework. Moreover, extended and minute comparisons of parts have as yet been almost wholly confined to anthropotomy, a branch of comparative anatomy which treats of a structure teleologically most perfect, but morphologically monstrous.

The legs are usually regarded as very simple and regular in their structure, because their only function is that of locomotion; but it is from this very cause that they are more complicated than the corresponding limbs of quadrupeds, for they are also the *only* organs of locomotion, and therefore are required to maintain the equilibrium of the erect body during progression, a duty which in the four-footed members of the class, is shared by the anterior extremities.

By a sort of favoritism shown to the anterior, and physiologically more noble region of the body, when the functions of prehension are transferred from the quadrupedal head to its diverging appendages, the arms, these are in their turn allowed to impose upon their posterior representatives their share in sustaining and propelling the body; but the latter. less highly favored, can merely make an awkward protest when the kangaroo throws upon the base of his huge caudal appendage the task of supporting his body while he kicks out with his hind legs, and when certain monkeys suspend themselves by the other end of their tails so as to leave all their limbs free.

The natural position of the quadruped is sustained in part according to *physical* laws, as is a table upon its four pedestals; but that of man is in direct defiance of these laws, which are ever ready to assert their rights the moment his will ceases to guard against them; and he, the lord of creation, is obliged to take his rest in an attitude other than that in which his superiority is exercised; his elevation is great, but according to the law of the succession of extremes, his fall is proportionately great, when the means of that elevation are withdrawn; he pays as it were, a physiological price for his physiological preëminence.

As in the arms of man were found extra muscles and articulations, with direct reference to the superadded function of rotation, so in the lower limbs there appears to be an increase in the number of muscles, and changes in the relation of those which are morphologically entitled to be present, in view of the fact that by two legs, instead of four, is the body to be propelled and its equilibrium maintained; therefore, they cannot be regarded as presenting the normal condition of parts for correcting our ideas as derived from the arms, since they are quite as fully, though less obviously and directly, under teleological influence.

The real extent of the antitypical relations between the anterior and posterior extremities must be learned from those vertebrates in whom they are actually *fore* and *hind;* and for this, when time and opportunity allow, such works as that of Strauss-Durckheim on "the Anatomy of the Cat;" of Della-Chiaje on that of the Testudo Europæa; and of Meckel on that of the Ornithoryncus, with the more comprehensive work of the latter anatomist, "Traité genérale d'Anatomie comparée," will be invaluable. Prior to these investigations, any such inferences as may now be drawn from the human structure must be regarded as provisional and by no means as conclusive.

It will now be shown to what extent our teleological morphology, as it were, of the long and the short muscles has been traced in the lower limbs of man. The ilium, unlike its longitype, the scapula, is firmly attached to the vertebral column, and does not, even in appearance, constitute a segment of the limb. Physiologically, the short and long direct flexors of the thigh are the *iliacus* and the *psoas magnus;* but the former is without doubt the morphological representative of the *subscapularis*, which is in man an internal rotator, but in most other mammalia an accessory flexor of the humerus; and the real antitype of the *teres major* is the small muscle first described under the name of *scansorius* by Traill, ("Observations on the Anatomy of the Orang-outang (Chimpanzee)" Memoirs of the Wernerian Natural Historical Society, vol. iii. Feb. 7, 1818;) afterward by Prof. Owen, ("Myology of Simia satyrus," Proceedings of Zoölogical Society of London, January 25 and May 30, 1831,) and lately by me, ("Contributions to Comparative Myology of Chimpanzee," Boston Journal Natural History, page 369, vol. vii.)

The long flexor of the humerus, *latissimus dorsi*, seems to have no posterior representative; the *glutæus maximus* at once suggests the *deltoid*, and may be the morphological as well as the physiological short extensor of the femur; while perhaps that portion of it which arises from the sacrum, represents the long extensor, corresponding with some one of the subdivisions of the *trapezius* of quadrupeds; for it must be remembered that when in them the clavicle is wanting, certain *contiguous* portions of the *trapezius* and *deltoid* become *continuous.*

The *glutæus medius* and *psoas magnus* are suggestive of the *supra* and *infra spinati*, and the *glutæus minimus* of the *teres minor;* the *pectinæus* represents the *pectoralis major*, and the *adductores brevis, longus* and *magnus*, are only excessive developments of what the *coraco-brachialis* is anteriorly; their great size in man being in evident relation, not only to his erect position but also to his firm seat on the noble animal which is to him strength and speed; but in the ape the rami of the ischia and pubes are lengthened downward, and so the adductors arising therefrom act powerfully as extensors of the limb in leaping.

The close antitypy between the direct extensors of the leg and those of the fore-arm has always been remarked, and Cruveilhier even gave to the former the name "*triceps femoralis.*" The *rectus*, like the scapular head of the *triceps humeralis*, is also the indirect flexor of the femur, the segment which intervenes between its origin on the ilium and its insertion upon the inner bone of the leg; the patella, a sesamoid bone developed in the tendon of the extensor, is generally considered to be the longitype of the olecranon process, both from their ordinary relations to the tendons of the muscles and from the fact that the latter is developed from a distinct osseous centre, and does in man sometimes exist as a separate piece connected to the shaft of the ulna by the continuation of the tendon. The *sartorius* resembles the muscle called "*epitrochlien*" by Duvernoy, and already referred to in this paper; but the former, since there is no long flexor of the femur, takes its origin from the anterior superior spinous process of the ilium.

But if the direct extensors of the leg are morphologically satisfactory, the flexors are quite the reverse, and in them is at once seen the effect of the twofold duties imposed upon the lower limbs; the muscles are too numerous, and most of them are long ones. The *semi-membranosus, semi-tendinosus* and *gracilis* attached to the tibia are apparently all accessory to the long head of the *biceps*, which, inserted upon the fibula alone, is probably the real long flexor of the leg, and thus the antitype of the *biceps humeri*, as the short head of the *biceps*, when it exists, is accessory to the *poplitæus* which is the antitype of the *brachialis anticus*, and thus the short flexor of the leg. Ordinarily, all the muscles of the lower extremity take their fixed point of action at the *distal* instead of the *proximal* ends of the several segments, and the accessory long flexors of the leg are evidently more important as mutually counteracting, and thus as balancing flexors and extensors of the pelvis, than as either direct flexors of the leg or indirect extensors of the thigh.

The direct extensors of the foot are, in man, very large, and two of them, the *gastrocnemius* and the *soleus,* with the enormously developed tarsal bone, upon which they are inserted, seem to bear relation to the above-named physiological necessity; however, they are very good long and short muscles accessory to the *tibialis posticus* and the *peronæus longus,* which seem to be the morphological short and long extensors; and in the Aï, (Bradypus tridactylus,) the latter muscle does actually take part of its origin above the knee-joint.*

The short flexor of the foot is the *tibialis anticus,* and the long the *peronæus brevis,* which in man is also made to act as an extensor by its tendon passing behind the outer malleolus, which, however, like the lower extremity of the fibula, is by no means constant in mammalia.

The toes are provided with a short and a long flexor, —*flexor brevis digitorum,* and *flexor longus digitorum,* — and with a short and long extensor with corresponding names; but the morphology of these, and their relations to those of the fingers, will be more easily learned from some animals in which there is more resemblance between the carpus and tarsus without any such prominence of one bone of the latter, as in most mammalia, and especially in man.

The following table may serve as a contribution toward a more complete understanding of the correspondences between the muscles of the anterior and posterior extremities:—

				ANTERIOR.	POSTERIOR.
1st. Segments. Humerus and Femur.	Flexors.	Long.		Latissimus dorsi,	?
			Ac.	Pectoralis major,	Pectinæus,
		Short.		Teres major,	Scansorius,
			Accessory.	Subscapularis,	Iliacus,
				Teres minor,	Glutæus minimus,
				Infra-spinatus,	Glutæus medius,
				Coraco-brachialis,	Adductors,
	Extensors.	Long.		Deltoid (spinal),	Glutæus maximus (sacral),
		Short.		Deltoid (scapular),	Glutæus maximus (iliac),
			Ac.	Supra-spinatus,	Psoas magnus,
2d Segments. Fore-arm and Leg.	Flexors.	Long.		Biceps,	Biceps (ischiatic head),
			Accessory.	Epitrochlien,	Sartorius,
				....	Gracilis,
				....	Semimembranosus,
				....	Semitendinosus,
		Short.		Brachialis anticus,	Poplitæus,
			Accessory.	Supinator longus,	Biceps (femoral head),
				Pronator radii teres,	
				Supinator brevis,	
				Pronator quadratus,	
	Extensors.	Long.		Triceps, (scapular head),	Triceps (rectus or iliac head),
		Short.		Triceps, (humeral heads),	Triceps (vasti or femoral heads),

*Meckel, "Traité Générale d'Anatomie comparée." Tome vi. page 413.

				ANTERIOR.	POSTERIOR.
3d Segments. Hand and Foot.	Flexors.	Long.		Flexor carpi radialis longior,	Peronæus brevis,
				" " " brevior,	Peronæus tertius,
		Short.		Flexor carpi ulnaris,	Tibialis anticus,
	Extensors.	Long.		Extensor carpi radialis,	Peronæus longus,
			Ac.	Palmaris longus,	Plantaris,
				....	Gastrocnemius,
		Short.		Extensor carpi ulnaris,	Tibialis posticus,
			Ac.	....	Soleus,
4th Segments. Fingers and Toes.	Flexors.	Long.		Flexor profundus digitorum,	Flexor brevis digitorum,
		Short.		Flexor sublimis digitorum,	Flexor longus digitorum,
			Ac.	Palmaris brevis,	
	Extensors.	Long.		Extensor proprius pollicis,	Extensor longus digitorum,
				" " indicis,	" " "
				" " minimi digiti,	Extensor proprius pollicis,
		Short.		Extensor longus digitorum,	Extensor brevis digitorum.

We have now seen the general plan, or the morphology, according to which the muscles of the mammalian limbs appear to be arranged, and also the general use, or the physiology of that plan; but in no case have we found it so closely adhered to as to exhibit what might be called a typical condition of the parts; everywhere we detect some variation according to the special functions of the muscles. The attachments of a muscle may be changed, as with the short flexors of the fingers; but this is far more common with respect to the *origins* than the *insertions,* if indeed the latter ever are changed; the origin of a muscle may be even duplicated, as in the *biceps humeri.* Quite often there are extra (accessory) muscles, as about the shoulder and hip; and of some of the latter (*obturatores internus* and *externus,* the *gemelli* and *quadratus lumborum,*) I have not yet been able to discover the morphology; occasionally, too, a muscle is deficient, at any rate in ordinary animals, as the longitype of the long flexor of the arm, *latissimus dorsi.*

We may not in every case be able to see the precise value of these variations from the general plan; nor can we even generalize them by asserting that they are more numerous and difficult to understand, at the two extremities of the limbs, as might be expected from the great mobility allowed by the ball-and-socket joints at the one, and the increased number and combined movements of the parts composing the other, and that the muscles are most regular in the intermediate regions of the limbs.

But whether we comprehend them or not, all these variations must have a foundation in use; for all morphology is for the sake of teleology; it is true the relation is also that of cause and effect; but each effect becomes in turn the cause of some use below it, while each cause is the effect of some power above it, till we reach Deity, from whom all things are. In their highest terms morphology and teleology are as Creator and Creation, as God and the Universe: the one can only be manifested through the other, which again is heterogeneous and scattered without the former. It is the universal principle of "concentrated representation;" many particulars uniting under one general, which in turn unites with others under a higher, and so on to Infinity.

Morphology and teleology *appear* as master and servant; but this is only an appearance of the relation when viewed *a posteriori;* and a view *a priori* shows that the reverse exists quite as truly. The advantages are mutually conferred, and it is only a division of labor. The commander of a company holds his position both *from* and *for* his men, and only thus can several companies be represented in a regiment, several regiments in a brigade, and so on up to the commander-in-chief, who really represents all beneath him; but what is he without them? Every superior is, or ought to be, more truly the servant of his inferiors, who while they appear to obey him really serve themselves. Broad as is our land, it cannot limit the application of our national motto. "*E pluribus unum*," is not merely a national motto, but the concise expression of an all-pervading law, the basis of the highest natural, human, and Divine order.

It may now be asked, Which is of the greater importance, and deserving of the more attention,—morphology or teleology, the general laws, or the particular facts and uses which they represent? The answer to this question will vary with the three degrees of depth to which our search is carried. At first we exclaim, "The *facts*, of course; they only have an actual existence, and are of any real use; they must be diligently collected and examined; they are strange and beautiful, and our wonder and admiration are constantly aroused." But there is something beyond this. The facts resemble each other, some more, some less, and soon we arrange them in groups, acknowledging, if such grace be given us, that those groups really did exist before we saw them; our minds are occupied with these; we give them names, and delight in contemplating the laws and principles they suggest to us. We find, moreover, that, though *immaterial*, they have a most *substantial mental* existence, and now we accord to this study the higher importance, and, mounted upon our philosophical superstructure, are inclined utterly to ignore the groundwork.

It is as if one had labored long in piling stones together to build a lofty tower, and at last standing upon the single block which forms the summit, forgot all below, acknowledging only himself and the result of his own work. If he stays there, it is clear that he can be of little use to himself or to any one else; he must descend and show to others the way up And now if he does this,—if he has employed his temporary elevation in looking abroad and beneath as well as above, and, more than all, if he imparts to others the superior information thus acquired, and instructs them that they also may ascend, then he has accomplished far more than if he had remained below surrounded and overwhelmed by the unarranged, and therefore uninstructive abundance, or had stayed at the top, proud and disdainful of those beneath him; and he now perceives that the former position was undesirable and the latter impossible without the other, and accords to each its true value in what he can accomplish with their combined assistance.

These three states of mind are respectively those of the unthinking but observant child, of the reasoning philosophical youth, and of the wise man who, having passed through both these stages, has attained to something better than either,—a power and a disposition to use what he has gained for others.

Three states are mentioned. There is really a fourth, but it is the first in the series, and corresponds to the embryo, which manifests no life, and is as it were the ground in which are implanted the others in their order. It is the stage of inactivity, of preparation, and it is easy to see the analogy between this and the lowest sub-kingdom of animals. The first and the last states seem in a measure to resemble each other on a lower and higher plane, as the vertebrate type stands over the radiate. And as the mature animal and the full-grown tree, in all their strength and beauty, expend their best energies in the elaboration of just such simple eggs and seeds as those from which they sprung, so the latter are the morphological epitomes of what may be, the other teleological expressions of what has been.

Among students of Nature, the three latter states of mind are respectively those of the mere collector or dissector; of the votary of morphology and classification alone; and lastly, of the favored few who happily combine them both, and thus accomplish more than with either one alone; and can we not see that the industry which has succeeded in accumulating such vast numbers of facts is already giving way to philosophical reasonings and a clearer comprehension of the same? The last stage of science is one to be striven for with full belief in its existence in the future.

ADDENDUM. For an extended definition and illustration of Teleology, see the chapter on Teleology of the Skeleton of Fishes, in Owen's Comparative Anatomy, Vol. ii.

NOTE. The foregoing paper, in a much less extended form, but containing most of the principal ideas, was originally prepared and presented as a Thesis at my graduation in the Department of Comparative Anatomy and Physiology in the Lawrence Scientific School of Harvard University in July, 1862. Since its revision I have received from Professor James D. Dana copies of the following papers by him: —

1. "On Cephalization." From the "New Englander" for July, 1863.

2. "On Parallel Relations of the Classes of Vertebrates, and on some Characteristics of the Reptilian Birds." From the American Journal of Science and Arts, Vol. xxxvi. Nov. 1863.

3. "The Classification of Animals, based on the Principles of Cephalization." Am. Journ. Science, etc., Vols. xxxvi. Nov. 1863, and xxxvii. Jan. 1864.

4. "On Fossil Insects from the Carboniferous Formation in Illinois." Am. Journ. Science, etc., Vol. xxxvii. Jan. 1864.

Also, from Norton Folsom, M. D., Surgeon of the 45th Regiment U. S. colored troops, the manuscript notes of an Essay by him "on Anatomical Symmetry," read at the Commencement of the Massachusetts Medical College, in July, 1863.

All these papers I have read with great interest and pleasure, not only for their intrinsic scientific value, but also because in some portions of them were contained confirmations of the ideas expressed in this paper, which confirmations are the more gratifying as coming from such masters in the science as Wyman and Dana, from the former of whom, Dr. Folsom writes, many of the ideas in his essay were derived.

I write this in order that the coincidences between the views in the papers above mentioned and my own may not be held to lessen the originality of what was written some months before those papers were read by me.

BURT G. WILDER,

Surgeon 55th Mass. Vol. Infantry.

CHARLESTON, S. C., August 11th, 1865.

Published, November, 1865.

III. *Enumeration of* Fossils *collected in the Niagara Limestone at Chicago, Illinois; with Descriptions of several New Species. By* Prof. ALEXANDER WINCHELL *and* Prof. OLIVER MARCY.

Read January 4th, 1865.

MORE than a year ago, some fossils came into our hands from the quarries in the south part of the city of Chicago, Illinois, in a suburb known as Bridgeport, which seemed to possess an unusual degree of interest. We at once visited the place, and subsequently adopted measures to procure as complete a collection as possible of the fossils of the locality. Believing that an exhibition of the ancient fauna which once lived upon the spot would possess considerable geological interest, we have made note of every species which has fallen under our observation, and, by an understanding with Mr. Worthen, the State geologist of Illinois, offer the results of our studies in the following paper: —

The rock at the principal quarry is a limestone, which, to a considerable extent, is in a broken and amorphous condition. The entire mass, in consequence of the partial or complete destruction of the fossils, has assumed an extremely vesicular structure. The upper portion seems to be somewhat magnesian; it is of a pale buff color, more massive than the lower, and contains nearly all the species enumerated in the present paper. Its thickness at the quarry is about eighteen feet. The lower portion is of a bluish color, generally harder in its solid parts, but somewhat diversified with patches of an argillaceous character. It has not been quarried to any considerable extent, and the excavations do not penetrate it a greater distance than about four feet. It is only in this part that we find those interesting species, *Acidaspis Ida*, *Ischadites tessellatus*, and *Gomphoceras Marcyæ*. The whole mass of the rock, both above and below, is a congeries of organic remains, three fourths of which are reduced to an unrecognizable condition, and many of which have been totally or partially dissolved out, showing, in some instances, the delicate tracery of the exterior, or complicated internal structure, in an extraordinary state of preservation.

We do not intend to be understood by what is stated above, of the upper and lower portions of the exposure, that in our opinion we recognize here the line of demarcation between two stages of the formation, not considering our data sufficient to justify a conclusion on this point.

According to Mr. Worthen, the rocks at this locality are lithologically and paleontologically identifiable with the Leclaire limestone at the upper rapids of the Mississippi, near Leclaire, Iowa, and Port Byron, Illinois.[1] Mr. Worthen states that a Bryozoan form resembling *Dictyonema retiformis*, *Myalina mytiliformis*, *Strophomena depressa*, a small *Pentamerus* resembling *P. galeatus*, and three or four species of chambered shells belonging to the genera *Orthoceras* and *Cyrtoceras*, are common to the Leclaire and Chicago limestones, establishing an identity between the two, as he thinks; while the Niagara age of the latter is shown by the number of Niagara species which it contains.

Professor Hall (Iowa Geol. Rep., p. 73,) had previously supposed the Leclaire limestone might be the western equivalent of the Galt limestone of Canada West, though he subsequently recognized the evidences of its belonging to the age of the Niagara group, occupying a position probably in the upper part of the group.[2]

[1] Amer. Jour. Sc. and Arts. vol. xxxiii. p. 46, 1862.

[2] Wiscon. Geol. Rep., pp. 67 *et seq.* and 446 *et seq.*

Our own investigations in the Chicago limestone — which are the first to bring into prominent notice this interesting locality — seem to confirm, beyond all controversy, Mr. Worthen's opinion of the age of the rock, as the following table will show; and by establishing, through numerous identifications, given below, its parallelism with the Racine limestone, — admitted to be equivalent to the Leclaire limestone,— it becomes geologically demonstrated that all these limestones occupy a position in the Niagara group of New York.

But with which member of the group shall they be synchronized? Our own identifications tend to show a relationship with both the Niagara limestone and the Niagara shale; of those species, however, which, at the East, occur in the Niagara shale, it will be observed that some, as *Strophomena rhomboidalis, Atrypa reticularis, Spirifera crispa, S. radiata, Meristella nitida,* and *Rhynchonella neglecta,* are species which enjoyed either a great geological or great geographical range, or both together, and are thus proved to have been wanting in that sensibility to geological variations which is requisite in fossils relied upon for stratigraphical determinations. The same may perhaps be said of *Caryocrinus ornatus* and *Loxonema subulata.* Of the others, the *Polyzoa* may be regarded as only provisionally identified. There is left, then, no strong bond of alliance between the Chicago limestone and the Niagara shale, except the prevalence of crinoidal remains in both. But it will be noticed that we have been unable to identify any species except *Caryocrinus ornatus;* so that, admitting the alliance shadowed forth by the presence of the crinoidal type in considerable force, we have a much stronger affinity established with the Niagara limestone by the identification of several species of true corals, as well as by the abundance of individuals of this type. For the present, therefore, it seems to us that the Chicago, Racine, and Leclaire limestones exhibit a satisfactory affinity with the Niagara limestone of New York.

We have detected in the Chicago limestone no less than eighty-two species, of which thirty-nine seem to be hitherto undescribed. If we add to these the few additional species described by McChesney, from the same locality, we find that a single quarry has furnished not less than eighty-seven species, — another evidence of the abundance and variety of life which teemed in the paleozoic seas.

None of the Gasteropoda or Cephalopoda have been identified with New York species. Of the identifications with New York species, the corals are all (except *Petraia calicula*) from the Niagara limestone, and the mollusks (including Bryozoa) are all from the Niagara shale.

It is noticeable that we do not find in our collection any specimens of *Heliolites, Eucalyptocrinus decorus, Orthis elegantula, Spirifera niagarensis, Pentamerus oblongus, Rhynchonella cuneata,* or *Calymene.*

Of the old species recognized by us, all have been described from the Niagara group of North America. *Loxonema subulata* Conrad, was, however, originally described from the Clinton group of New York, but has been identified in the Niagara group of Canada West, as well as at Chicago. The geographical distribution of these species in some of the Northwestern States, Canada West, and Europe, is presented at a glance in the following table:

GEOGRAPHICAL DISTRIBUTION OF NIAGARA SPECIES IDENTIFIED AT CHICAGO.

	N. Y.	WIS.	IND.	CAN.	EUR.
Petraia calicula Hall sp.	*			*	
Zaphrentis turbinatus Hall sp.	*				
Diphyphyllum cæspitosum Hall sp.	*	*			
Favosites gothlandica Lam.	*	*	*	*	*
" venustus Hall sp.	*				
Cladopora fibrosa Hall	*				
" seriata Hall	*				
" reticulata Hall	*				
Halysites catenularia Linn. sp.	*	*	*	*	*
Stictopora punctipora Hall	*				
Polypora incepta Hall	*				
Fenestella elegans Hall	*				
Lichenalia concentrica Hall	*				
Eucalyptocrinus ornatus Hall		*			
Glyptocrinus Carleyi Hall			*		
Caryocrinus ornatus Say	*	*		*	
Caryocystites cylindricus Hall		*			
Strophomena rhomboidalis Wahl.	*	*	*	*	*
Atrypa reticularis Linn. sp.	*	*	*	*	*
" nodostriata Hall	*				
Meristella nitida Hall sp.	*		*	*	
Spirifera crispa Sowb.	*		*	*	*
" radiata Sowb.	*	*	*	*	*
Rhynchonella neglecta Hall	*	*	*	*	
* Pterinea neglecta McChesney sp.		*			
Ambonychia mytiloidea Hall		*			
Pleurotomaria Halei Hall		*			
" Hoyi Hall		*			
Loxonema subulata Con.				*	
* Orthoceras Laphami McChenesy		*			
Cyrtoceras Fosteri Hall		*			

ENUMERATION OF SPECIES.

Petraia calicula Hall sp., Pal. N. Y., ii. p. 111, pl. xxxii. fig. 1, *a – k*.

Zaphrentis turbinatus Hall sp., Pal. N. Y., ii. p. 112, pl. xxxii. fig. 2.

Cystiphyllum sp? A fragment generically well marked.

Diphyphyllum cæspitosum Hall sp., Pal. N. Y., ii. p. 116, pl. xxxiii. fig. 1, *a – b*.

Favosites gothlandica Lam. (F. niagarensis Hall.) We adopt the suggestion of Billings (Canad. Journal, March, 1859, p. 99), in referring this form back to the original species. It occurs abundantly in the upper part of the quarry.

Favosites venustus? Hall sp., Pal. N. Y., ii. p. 120, pl. xxxiv. fig. 1, *a – i*.

The agreement is not striking. This is an expanded, incrusting coral, adapting itself to the inequalities of the underlying surface, and, in places, developing tubercular masses. The tubes are ordinarily not more than an eighth of an inch long, but, in the tubercles become sometimes half an inch in length. In the tuberculous parts, the diaphragms are seen to be direct and crowded. No indications of a radial system are seen. The cell-mouths are conformable to this species. The Chicago fossil bears considerable resemblance to *Thecostegites hemisphæricus* Röm. (Sil. Fauna des Westl. Tenn. Taf. ii. fig. 3).

* These species are not enumerated by Hall among the fossils of Wisconsin.

Cladopora Hall.

Cladopora lichenoïdes W. and M.

Plate II. figure 1.

Polypary consisting of a mass of crowded cylindrical tubes arranged in ramose and foliaceous forms, both forms being sometimes united in one specimen. The earlier growth, in one of our specimens, is explanate. The cells are elongated, obliquely horizontal, crowded, overlapping, with their mouths opening obliquely through the epitheca. The frond develops into an irregularly undulate form, sometimes dividing, and some of the lobes bending round laterally, after the manner of one or two turns of an *Archimedes*. From the border of the frond arise terete, bifurcating branches, with the mouths opening on all sides. All the cell-mouths are somewhat crescentiform, the outer lip often slightly indented, and sometimes sufficiently so to give the mouth a triangular outline.

In exfoliated, weathered specimens, the cells are seen to be cylindrical and separately walled, but closely in contact. The width of three of these cells occupies the space of one tenth of an inch; their length is about a third of an inch. No evidences of septa or lamellæ can be detected.

The cell-mouths of this abundant and beautiful species resemble *Cœnites*, *Alveolites*, and *Cladopora*. The fossil differs from *Cœnites* and *Cladopora* in not having a solid cœnenchyma, and—at least from the usual forms—in its foliaceous *ensemble*. It differs from *Alveolites* in the want of intra-cellular structure. Some species of *Cladopora* figured by Hall, however, exhibit generic characters to which the present species is sufficiently conformable.

Cladopora verticillata W. and M.

Plate II. figure 2.

Corallum arising in the form of a stem, from which spreads out, horizontally, in all directions, a thin and delicate frond, composed of small radiating cells continually multiplying in number with the distance from the axis. This circular frond is covered superiorly by an epitheca through which the cell-mouths open as in other species. The mouths are triangular-crescentic; the cells show traces of dissepiments. At the height of an inch and a half above the first frond is another, in all respects similar, and a cylindrical perforation runs through the rock from one to the other. This structure has been seen in two unmistakable specimens. It seems probable that other verticils or circular fronds occur between the two observed, and that the whole space was originally filled up with verticils of cells alternating with plates of epitheca; but of this we have no other evidence than the porous condition of the rock, with occasional traces of minute coral tubes.

In the specimen which is the subject of this description, a second stem, smaller than the first, is seen perforating the rock for the depth of half an inch, and sending out a verticil which becomes confluent with that of the larger specimen. Is this a new colony rooted, banyan-like, from the branches of a parent?

The axis in our specimens is hollow. The filling is a calcareous clay, showing no other structure than a slight porousness, with obscure vertical striations on the exterior. We might be permitted to infer, from analogy, that the original axis was solid, and resembled the cylindrical stems of other species of the genus, but has been destroyed in our specimens.

Diameter of the hollow axis, .16 below, .19 above ; diameter of verticils, more than three inches ; number of cells in one tenth of an inch, 6 to 8.

Much remains to be learned of this coral ; and we desire to direct attention to it by making known, in the mean time, its very extraordinary *ensemble*. The two species of *Cladopora* described by us not only present unique characters in their general forms, but, in their structure, furnish us with the proofs that *Cladopora* is a generic type founded in nature.

Cladopora fibrosa Hall. Pal. N. Y., II. 139, pl. xxxviii. figs. 4, 5.

Cladopora seriata Hall. Pal. N. Y., II. 137, pl. xxxviii. fig. 1.

Cladopora reticulata Hall. Pal. N. Y., II. 141, pl. xxxix. fig. 3. We have specimens of this exhibiting the reticulations spread over a surface eight or ten inches square.

Halysites catenularia Linn. sp. Seldom found in a recognizable state of preservation. We occasionally find casts of the spaces enclosed by the labyrinthine walls, which, with the vertical striations and transverse wrinkles of the tubes preserved, present an object closely resembling the enigmatical fossil named *Cophinus dubius* in the Silurian System, (pl. xxvi. fig. 12,) and which in the Siluria (p. 136, and pl. xv. fig. 4) is attributed to the slow gyration of the stems of encrinites after the mud had settled around them. The Ludlow fossil may clearly have had the origin attributed to it ; but our specimens, though at first obscure, have furnished, at length, conclusive evidence of being the impressions or casts of the walls of a *Halysites*. The transverse dissepiments in some of the cells are well preserved and numerous.

Stromatopora sp ? We have a weathered specimen, exposing the stellately diverging ramulets formed in the interlaminar spaces. This curious organism would not ordinarily be identified as a *Stromatopora ;* but, by the aid of Dr. Röminger's extensive suite of specimens of this genus, its true character becomes apparent. There is a specimen of the type, which shows stellate cell-mouths, in the Illinois State Cabinet. This is in the usual state of preservation, and may be identical with ours, though we have only had the opportunity to give it a hasty glance.

Stictopora punctipora? Hall. Pal. N. Y., II. 157, pl. xl. B, fig. 2 *a–e*.

Polypora incepta ? Hall. Pal. N. Y., II. 167, pl. xl. D, fig. 5 *a–f*. A large undulately cyathiform frond, nearly six inches in diameter, with fenestrules somewhat smaller than in the typical species. The cells have not been certainly distinguished either in this or the following species.

Fenestella elegans ? Hall. Pal. N. Y., II. 164, pl. xl. D, fig. 1 *a–g*.

Lichenalia concentrica Hall. Pal. N. Y., II. 171, pl. xl. E, fig. 5, *a–g*.

Ischadites Murchison.

Ischadites tessellatus W. and M.

Plate II. figure 3.

Body somewhat tapering, pyriform, compressed on the side toward which the smaller end is slightly inflected ; the larger end imperfect in all our specimens. One example is somewhat in the form of a triangular prism with rounded edges, and the sides indented toward the base, while the upper end is convex. The whole exterior is divided into small rhomboidal or nearly square areas by ridges which originate at the apex and describe curves obliquely approaching the base, and crossing each other like the curves of the "engine-turned ornament of a watch." In the best preserved specimens, these ridges are surmounted by little crests deepening the pits or cells which they mark out. In other specimens these cells are simply hopper-shaped cavities. The cells of course increase in size from the origin of the ridges to that part of the surface where the diameter of the body is greatest. In the bottom of each cell is a small pore penetrating the internal cavity. Besides this, each cell communicates by pores with the four neighboring cells touching it at the angles. These connecting pores are parallel with the general surface, and pass under the intersection of the two crests or ridges. Each rectangular intersection, therefore, rests over the crossing of a couple of right-angled passage-ways. In some specimens, in which the hopper-shaped cells are shallow, these pores, extending across the cell from corner to corner, present the appearance of open passage-ways excavated through the substance of the test; on the side toward the larger end of the body, however, the passage-way remains covered. In such cases, the feature which first strikes the eye is a pair of furrows intersecting each other at right angles in the middle of each cell, forming three sides of a cross.

Our specimens are all casts, and exhibit no further internal structure, except that the central pores can be seen penetrating the internal cavity, and losing themselves at the depth of a quarter of an inch. Polished sections at right angles with the surface present obscure indications of sac-like cells extending inward from the surface about one fourth of an inch. There is one of these on each side of the central pore, and the inner end of the cell is regularly rounded. The pore seems to have been the means of communication between the inner common cavity of the body and the external element. It was perhaps respiratory in its function. The cells present the appearance of individualization, while the entire body was undoubtedly a compound organism. Polished surfaces at right angles with the larger axes of these cells do not succeed in bringing their walls into view.

No peduncle of attachment appears to have been in connection with the smaller end; but the larger ends are all imperfect, and it seems not unlikely that this end was adherent, or possibly pedicled.

The largest and most perfect specimen is 2.5 inches in length, with a maximum diameter of 1.75 inches. The diameter of the cells over the most swollen portion of the body is .09 inch.

These very interesting and beautiful specimens are evidently congeneric, if not conspecific with *I. Kœnigi* Murchison,[1] and *I. canadensis* Billings, (Geol. of Canada, pp. 309, 327,) though the entire form of *I. canadensis* has not been figured, and *I. Kœnigi* is less attenuate at the smaller end. We are of the opinion, also, that they possess close relations with *Dictyocrinus* Conrad, and *Tetragonys* Eichwald; and that all these genera belong to the same zoölogical type as *Receptaculites*, which has been shown by Salter to be one of the *Foraminifera*, as D. D. Owen conjectured in 1844. At least, the affinities of *Ischadites* with *Receptaculites* seem to be pretty clearly shown by our specimens; and it is worthy of remark that Morris, in his Catalogue, has united *I. Kœnigi* and *Receptaculites Neptuni*, while Professor Hall says, (Pal. N. Y., III. p. 148): "The figures [of *I. Kœnigi*] in the Silurian System bear so close a resemblance to *Receptaculites* that I could scarcely regard them as distinct from that genus."

1 Silurian System, 697, pl. xxvi. fig. 11; Siluria, pl. xii. fig. 6.

ACTINOCRINUS Miller.[1]

Actinocrinus obpyramidalis W. and M.

Plate II. figure 4.

Body pentangularly obpyramidal; radial series standing out in salient angles with depressions between, deepening upward, and giving great prominence to the arm bases, which are quite small, and exist in pairs. Dome arched, with the appearance (in our specimens) of a broken proboscis a little nearer the centre than the anal side.

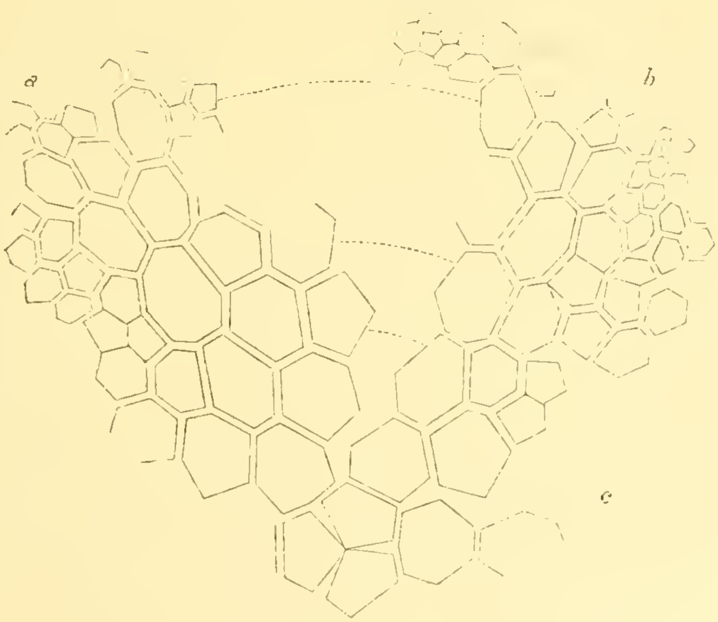
Basal plates not seen; radials three, the two lower hexagonal, the first a little larger than the other two, and having its upper side shortest; the third radial heptagonal, supporting a pair of hexagonal secondary radials upon its upper sloping faces. The other plates of the cup cannot be satisfactorily defined in our specimen. They give evidence of having been elevated and sculptured. We have seen a specimen 1.75 inches high to the top of the dome.

This species has all the general appearance of an *Actinocrinus*, and resembles such Carboniferous species as *A. quinquelobus* and *A. cornigerus;* and was not improbably furnished, like them, with spines upon the dome. We know of no allied species of the same geological age.

MEGISTOCRINUS Owen and Shumard.

Megistocrinus Marcouanus W. and M.

Plate II. figure 5.



a. Left antero-lateral ray. *b.* Left postero-lateral ray.
c. Azygos side, with one half of the azygos interradials.

[1] Learning, after we had engaged in this investigation, that Mr. W. H. Niles, of the Museum of Comparative Zoölogy at Cambridge, was occupied in a reinvestigation of *Crinoidea* with a view to publication, we should have preferred that our own specimens of that type should be worked up by him. He has, however, insisted on our proceeding independently; and, having done so, we deem this statement demanded by the courtesy which ought to prevail among co-laborers in science.

Body large and massive, somewhat obconic, spreading more rapidly towards the arm bases; base sub-acute, generally turned to one side. Basal plates three, equal, hexagonal — the inner side very short — a little broader than high. Radials three in each series. Of the first radials three stand opposite the three basals, and are hexagonal, a little higher than wide, the upper side being shortest, the lower next in length. The other two first radials stand opposite the division between two basals; they are heptagonal by the division of the base, the two basal sides, however, lying nearly in the same straight line. The second radials are hexagonal, nearly as large as the first, one fifth longer than wide, the upper and lower sides about half the length of the others. The third radials are larger than the second, octagonal in the anterior and antero-lateral rays, having two upper sides, each of which is about equal to the lower one, the lateral sides being considerably the longest, and thus causing this plate to be longer than broad; in the postero-lateral rays they are heptagonal by the enlargement of the anal plates. The first supraradial plates are irregularly heptagonal, two thirds as large as the third radial. Second supraradials heptagonal or octagonal, of the same size as the first or smaller, supporting on their upper sloping sides a pair of small pentagonal brachials. Number of arms twenty. First regular interradial hexagonal, nearly as large as the first radials, supporting on its shorter upper sides a pair of smaller interradials, which are succeeded by about ten other interradials, making thirteen in all. The azygos, or anal interradials number about thirty. The first rests upon the basals, and has precisely the same form and size as the antero-lateral first radials; like the radials, also, it is succeeded by two others, producing a series resembling the true rays, differing, however, in the plates, being a little smaller than the true radials, and being succeeded by five other smaller plates nearly in the same line. Between this series of anals and each contiguous ray lies a series of three plates followed by two pairs. First intersupraradial hexagonal, surmounted by two pairs of smaller ones. The formula of this species is, therefore, as follows: —

Basals	3
Radials $3 \times 5 =$	15
Supraradials $2 \times 2 \times 5 =$	20
Brachials $2 \times 2 \times 2 \times 5 =$	40
Regular Interradials $13 \times 4 =$	52
Azygos Interradials	30
Inter-supraradials $5 \times 5 =$	25
Interbrachials	0
Total plates in the cup	185

One of our specimens is 3.4 inches long, to the bases of the arms. Another one, defective below, has a diameter of three inches at the bases of the arms; most of the specimens are not over half this size.

There is a variety of this species (apparently) which is marked by ridges along the series of radials and secondary radials. These ridges (in casts) are not interrupted by the sutures.

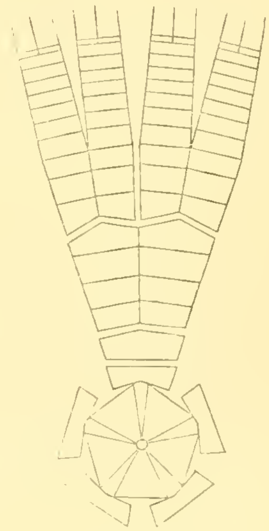
This massive species bears a remarkably close affinity with *Actinocrinus Christyi* Hall, (Notice of Waldron Fossils, p. 2,) but it may be discriminated as follows: The first radial has a height greater than its width, instead of being equal to it; the second radial is higher than wide, instead of the reverse; the third radial is octagonal in the antero-lateral rays, and is larger than the second, instead of smaller; the regular interradials are fewer in number, instead of fifteen or over. Lastly, the ridges over the radial plates are entirely wanting in the typical specimens, and in the supposed variety are not interrupted by the sutures. It is quite possible that the structure of the supposed variety may conform completely to that of *A. Christyi.*

It will be observed that this species departs from the usual form of *Megistocrinus* as known in the Carboniferous rocks, at the same time that it falls strictly under the formula of that genus. We feel constrained to say that the same is true of *Actinocrinus Christyi* Hall, — a circumstance which will enable us to perpetuate this preoccupied specific name under the form of *Megistocrinus Christyi.*

Ichthyocrinus Conrad.

Ichthyocrinus corbis W. and M.

Body pyriform, section nearly circular, one specimen flattened and even indented on the anal side; greatest diameter at one third the height of the body below the arm bases; oblique height gradually or rather rapidly curved below, and more rapidly curved in the vicinity of the greatest diameter, giving the body, in most specimens, a sub-ventricose appearance. Stem very slender at the upper end, turned to one side in all our specimens. Basal plates five, equilaterally triangular, slightly truncated by the stem at their lower apex, flattened, so that the five sutures by their prominence convert the pelvic cup into an inverted pentagonal pyramid. Radials two in each ray, alternating with the basals, which project their angles in pairs into the lower sides of the first radials, rendering them pentagonal by a reëntrant angle below; second radials also pentagonal, with two upper sloping faces to receive the secondary radials. Secondary radials four in each series, each with a transverse diameter equal to twice its height or more; the fourth with two upper sloping sides for the support of the tertiary radials, which are about nine or ten in number in each radiating series, gradually diminishing in height from below upwards, while they increase in transverse diameter, so that the uppermost plates are not more than one twentieth of an inch in vertical height, while their transverse dimension is one fourth of an inch.



Ichthyocrinus corbis.
Showing the plates of one ray.

In one of our specimens the height of the body to the bases of the free arms is 1.8 inch; greatest diameter (.55 inch below the free arm bases) 1.62 inch. In another specimen, less ventricose, the height is 2 inches, and the greatest diameter (.66 inch below the free arm bases) is 1.6 inch.

The distinctive characters of the species are the small size of the stem, the large size of the basal plates, corresponding to the sides instead of the angles of the pentagonal base, the presence of two instead of three radials, and the perfectly straight transverse sutures separating the plates of the several radial series, except the suture separating two successive series.

In the specimens which we have for examination, the exterior of the plates is removed, and the filling of the sutures projects conspicuously, giving the body a peculiar basket-like or net-like appearance. The characters about the base are somewhat obscure, and it is possible we have overlooked the real first radial. This supposition would reduce the fossil to a greater conformity with *I. lævis*, but it would still be distinct.

GLYPTOCRINUS Hall.

Glyporcinus Carleyi? Hall. Notice of Waldron Fossils, p. 19. We have several specimens, in a poor state of preservation, which evidently belong to *Glyptocrinus*, or one of the allied genera. We are inclined to think the basal plates are entirely covered by the stem. The radials are three in each series. A conspicuous ridge runs along the middle, bifurcating at each end, in the centre of the first and third radials. The lower branches of the ridges proceed to the centre of the subradials. The azygos interradius is broader than the others, and contains a plate with radiating ridges. The whole number of interradials cannot be determined. The form of the cup is pentangularly turbinate, about three fourths of an inch high, with the same diameter at the bases of the arms. In form, size, and disposition of the visible markings, our specimens agree with specimens from Waldron.

Glyptocrinus sp.? A species quite distinct from the last, being more slender, with a more attenuate base, and more spreading rays. Our specimens also are of smaller size.

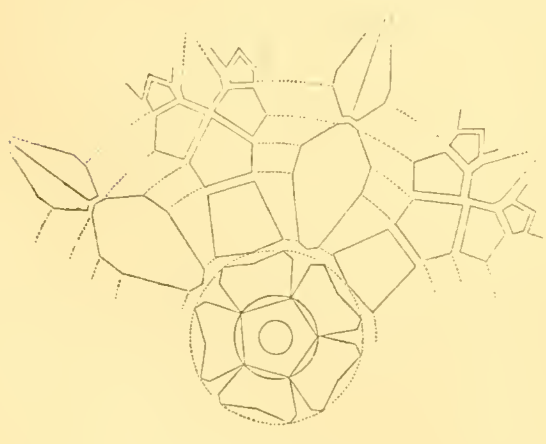
LECANOCRINUS Hall.

Lecanocrinus pusillus W. and M.

Body small, depressed, broader than high, constricted above the first radials. Basals small, two hexagonal and one pentagonal. Subradials pentagonal and hexagonal, each equal in size to the whole base. Radials three in each ray, — the first five-sided, having the upper side longest. the basal sides next in length, and the remaining two parallel with each other; second radial quadrangular, short, being five times as broad as high; third radial with two upper sloping faces supporting a pair of secondary radials. Secondary radials transversely oblong, quadrangular; no more than three have been seen. Height to base of arms, .24 inch; diameter at base of arms, .40 inch.

EUCALYPTOCRINUS Goldf.

Eucalyptocrinus chicagoënsis W. and M.



Eucalyptocrinus chicagoënsis.

Body massive, obconic from the base to the arms; base truncate, deeply impressed, obscurely pentagonal, the rim of the impression presenting five protuberances corresponding to the intervals between the first radials. Basal plates small, concealed within the basal cavity. First radial plates quadrangularly heptagonal, the upper side presenting an obtusely reëntrant angle. Second radials as large as the first, nearly square, but having the lower side angulated to suit the reëntrant angle of the first radial. Third radials hexagonal, or very nearly pentagonal, the lower lateral sides being relatively short, and the upper side almost zero. First supraradial smaller than the third radial, irregularly pentangular. Second supraradials less than half the size of the first, pentangular, with the lower lateral sides shortest, each upper side supporting a small triangular piece, upon which rests the first arm plate. The interradial plates are one large and two smaller to each interradius. The general outline of the lower is somewhat kite-shaped; it is bounded by ten contiguous plates, but the two lower lateral sides are so crowded by the bounding second radials, that the two lower sides touching the first radials are extremely short; and the two short upper sides, in contact with the second interradials, lie nearly in the same line. The pair of smaller interradials are nearly as long and broad, taken together, as the first interradial; the greatest width is below the middle, and their summits reach higher than the bases of the arms. The intersupraradial is similar in shape to the pair of upper interradials, but smaller, and the lower side is almost zero, touching the apex of the third radial. Height of cup to bases of arms, 1.1 inch; greatest diameter (at arm bases), 1.7 inch.

This species greatly resembles *E. crassus* Hall, but a comparison of numerous specimens of each shows constant differences. The first radial is of nearly the same width as the second, instead of being much wider; the first interradial is more elongated, and the two lower sides together are not one fourth the length of the two corresponding sides in *E. crassus.* The second interradials are also more elongate, and narrower. The base shows a tuberculately pentagonal form not possessed by the Waldron specimens.

Eucalyptocrinus ornatus Hall. Wis. Geol. Rep. 1861, p. 20. Differs in no way from Hall's description, except that the first interradial plate is a little higher than wide; and our casts do not exhibit the characters of the exterior.

One of our specimens possesses a sub-central proboscis, of which three eighths of an inch are preserved, exhibiting such a taper that the entire length would seem to have been five or six eighths of an inch. Only the cast of the proboscis exists. The dome is depressed, and the base of the proboscis is elevated about three eighths of an inch above the arm bases. This is a common species, and may be at once distinguished from *E. chicagoënsis* by its much more depressed and generally sub-hemispherical body. This is probably the species mistaken by Worthen for *E. decorus*, which it resembles in form while it is amply distinct in the details of the plates.

Caryocrinus ornatus Say. This species is common, and many of the specimens exhibit, by the removal of the exterior, the grooves running from the pores to the margins of the plates, as shown by Hall, Pal. N. Y., II. pl. xlix. fig. 1, *u.* The external impression of the body is sometimes extremely well preserved.

Caryocystites cylindricus Hall. Geol. Rep. Wis. 1861, p. 23; figured in Rep. for 1862, p. 69. The ovarian aperture, not seen in the typical specimens, is very distinct in a fine specimen belonging to the Chicago Academy of Sciences.

Strophomena Raf.

Strophomena macra W. and M.

Plate II. figure 8.

Shell thin, with both valves nearly plane in young specimens; general outline semicircular, but with a straight hinge-line projecting somewhat at the lateral angles. Ventral valve very slightly elevated in the umbonal region, deeply concave nearer the border in old individuals, having a long, moderately wide area with a triangular fissure; divaricator scars a pair of small, feeble, diverging pyriform impressions, separated by a faintly raised rostral septum, which reaches two fifths the length of the scars. Inside of valve showing numerous faint. irregularly distributed radiating ridges which become visible about midway between the beak and the margin. Sometimes one or two feeble concentric wrinkles a little beyond the middle of the valve. The exterior is very differently marked. It presents a series of shallow, flattish-concave, radiating furrows, separated by abruptly raised, narrow, sharply carinated costæ. The latter double in number near the middle of the valve by implantation in the middle of the intervening furrows.

Length of hinge-line of large specimen, 1.8 inch; length of shell from beak to front margin, 1.21 inch; transverse diameter of fissure, .39 inch; greatest width of area, .15 inch; depth of ventral valve, .04 inch; length of divaricator scars, .5 inch.

In outline and surface characters of the casts of young individuals, this species resembles *Leptæna sericea* Sow., but the divaricator scars are very much smaller, differently shaped, and more feebly impressed. It is also a leaner shell, and on the inside shows but faintly the costal impressions which can be so plainly traced around the margin of that species. It differs similarly from *Streptorhynchus subplanus*, its nearest analogue in rocks of the same age. The characters of the exterior, and of the adult shell present, on the contrary, few resemblances to the species with which we have compared the young.

Strophomena niagarensis W. and M.

Plate II. figure 9.

Shell of large or medium size, somewhat hemispherical, hinge-line equal to the greatest width, producing a semicircular outline. Ventral valve extremely ventricose, regularly arched from beak to anterior margin, most elevated in the middle, flattened toward the hinge extremities; beak depressed, incurved, not surpassing the hinge-line. Area moderately elevated in the middle, with a broad triangular foramen, situated nearly in the plane of the commissure of the two valves, delicately striated transversely. Divaricator scars elongate-ovate, but slightly divergent, reaching one third the length of the valve; occlusor scars narrowly linear, closely approximate; rostral septum low, one third the length of the divaricator scars. Internal surface of shell finely papillose in the region between the muscular scars and the hinge-line; the entire inner surface marked with very fine, irregular, wavy striæ. Ventral valve sometimes with a shallow undefined sinus each side of a low median ridge.

Length of hinge-line, 1.58 inch; length of shell, 1.34 inch; convexity of the ventral valve, .50 inch; length of divaricator scars, .65 inch.

We have endeavored to unite this species with some of those already recognized. It belongs to the group embracing *S. inæquistriata, hemisphærica*, etc. which are the nearest related American forms. In outline it resembles the first, but the beak is less projecting, and the striæ are much finer. Unlike *S. hemisphærica* it has no concentric wrinkles or other markings; and the hinge-line is proportionally longer, the muscular scars more elongate and narrower, and the whole structure about the hinge is bolder and stronger. Neither does *S. hemisphærica* exhibit the internal granulations so conspicuous in our species. We think, too, that our species is always even more ventricose than the other. Amongst known fossils of the same age, there are none closely related. The resemblance of *S. subplanus* and *S. semifasciata* is quite superficial, and no more can be said of *S. patenla* of the Clinton group. Amongst foreign species it approaches nearest to *S. imbrex* Pander and Davidson.

Strophomena rhomboidalis Wahl. Numerous excellent examples of the middle-silurian type, showing both external and internal characters. We shall probably discover grounds hereafter for a division of this nominal species.

Streptorhynchus King.

Streptorhynchus hemiaster W. and M.

Plate II. figure 10.

Shell small, semicircular, hinge-line the longest diameter; in some specimens slightly auriculate. Ventral valve depressed-convex, with an abruptly elevated beak, truncated by the area on the cardinal side, and gently twisted toward the right; area triangular, nearly at right angles with the plane of the shell, its fissure closed by a convex pseudo-deltidium of one piece. Surface marked by straight, sharp, radial costæ which double in number by implantation at about one third the distance from the beak to the margin, and double again nearer the margin. Dorsal valve flat, appearing, in the condition in which we find the specimens, to be constituted by a series of radiating, rounded, threadlike ribs which show most conspicuously on the inside, the principal ones extending from the beak to the margin, and increasing in number by implantation.

Length of hinge-line .38 inch; length of shell .23 inch; height of area of ventral valve .10 inch.

Atrypa reticularis Dalm. sp. Abundant, often exhibiting the internal structure in a beautiful state of preservation.

Atrypa nodostriata Hall. Pal. N. Y., II. 272, pl. lvi. 2. Common, in an imperfect condition, but in some instances exhibiting the spiral armature.

Trematospira Matthewsoni McChesney. New Paleozoic Fossils, p. 71.

Athyris nitida Hall sp. Pal. N. Y., II. 268, pl. lv. 1, 2. Occurs in the typical form, and the variety *oblata* Hall.

Nucleospira sp? A small pyriformly ventricose species, exhibiting the internal structure, but too imperfect for description. We suspect this is the species referred to by Hall (Iowa Rep. p. 73, note), as a *Spirigera*, occuring at Leclaire, Iowa, in great numbers.

Spirifera Sow. Martinia McCoy.

Spirifera (Martinia) similior W. and M.

Outline subcircular, transverse diameter greatest, gently rounded from the sides to the cardinal margin; hinge-line about two thirds the greatest width of the shell. Ventral valve ventricose, gently convex to the very margin on all sides, deepest at about one third the distance from the beak to the anterior margin; beak incurved and slightly surpassing the hinge-line, overhanging a large triangular fissure, without noticeable area. A trace of a mesial septum extends from the beak one third the length of the valve. In some specimens no sinus whatever can be discerned; in others, a shallow and obsolete one; in others still, one or two inconspicuous undulations each side of a mesial sinus. Surface of cast otherwise smooth, or with numerous fine concentric wrinkles. In one specimen faint radiating lines may be doubtfully detected.

Length of shell, .57 inch; transverse diameter, .80; height of umbo of ventral valve, .31 inch.

In its smooth exterior, and gently undulate margin, this species calls to mind *Spirifer bicostatus* Hall; and we were at first inclined to regard it as a variety of that species; but the beak is always less prominent and less incurved, and the sinuations of the exterior are much less apparent, and in some specimens entirely wanting.

It is an abundant species at Chicago; and in some instances one of the spires has been found in a complete state of preservation, showing that it consists of seven turns conically arranged.

Spirifera radiata Sowerby. Silur. Sys. 637, pl. xii. fig. 6, and 638, pl. xxi. fig. 5. Very good ventral valves of this species occur, and in one instance, a fine specimen with the valves united. Another specimen exhibits the internal structure, showing that the spire is a delicate hollow tube of about 14 turns, of which 11 are preserved. In these specimens it is interesting to observe that the margin is distinctly plicated, as in the Dudley specimens from England. According to Hall, (Pal. N. Y., II. 265,) this character is not observed in the New York specimens of the species. Neither does it occur in specimens in our possession from Waldron, Indiana.

Spirifera crispa Sowerby. Silur. Sys. 624, pl. xii. fig. 8. Each spire has about ten turns, the first of which corresponds to the sinus bounding the mesial elevation. The crus expands into a little plate and becomes coincident with the dental lamella of the opposite valve. A little curved, barb-like branch departs from each of the crura, on the ventral side, and the two perhaps meet together in the manner of *Zygospira* Hall, though in a different position.

PENTAMERUS Sowerby.

Pentamerus chicagoënsis W. and M.

Plate II. figure 11.

Shell of moderate size, the commissure, (including the hinge-line) presenting a somewhat semicircular outline; but in consequence of the prominence of the beak of the ventral valve, the outline presented by a view from this side is obtusely sectoral. The ventral valve is very ventricose, with the beak recurved over that of the dorsal valve. The highest point of the convexity is two fifths the distance from the beak to the front margin. A narrow, rather deep and distinct sinus extends from the umbo to the anterior margin, which is bounded on each side by a stout obtuse rib considerably elevated above the general contour. In other words, this valve may be said to present a median ridge which is deeply divided in the middle. Following each of the median ribs are three others, smaller than the two middle ones, and of which the first is less developed than the other two. The last two ribs only reach half way to the beak. Still nearer the right and left extremities the surface seems to be plane, but near the beak are five or six radial striæ on each side. No other surface markings are visible either on the shell or the cast.

Length from beak to anterior margin, .65 inch; greatest transverse diameter — lying midway between the anterior and cardinal margins — .65 inch.

The form of this species is similar to that of *P. galeatus* Dalman, but the extremities are less rounded, and the costæ are fewer and less regular. It is related to *P. trisinuatus* Mc-

Chesney, but our species has two additional ribs on each side of the ventral sinus. We have not access to Hall's description of *P.? ventricosus* from the Niagara limestone of Wisconsin.

Rhynchonella neglecta Hall. Pal. N. Y., II. 274, pl. lvii. fig. 1, *a – p*.

Pterinea (Goldf.) Meek.

Pterinea volans W. and M.

Shell large, very oblique, with an extended hinge-line, and alate posterior extremity. General outline nearly semicircular. Left valve moderately inflated anteriorly, flattened in the posterior half; beak small, nearly terminal, incurved, not surpassing the hinge-line; whole pallial outline regularly circular, except a rather deep sinus beneath the posterior hinge extremity. Cartilage facet not certainly determined; in one small specimen it appears to be very wide, with four or five furrows. External surface marked by strong ribs which bifurcate and become wavy beyond the middle in old shells; the ribs becoming abruptly much smaller on the posterior wing. Besides the ribs, the superficial layer of the shell is cancellated by strong concentric and feeble radiating ridges. The costæ show distinctly on the cast, except on the posterior wing.

Length of hinge-line, 2.1 inches; greatest height of shell (at middle of hinge-line,) 1.5 inch; convexity of left valve, .26 inch.

This species differs from *P. striæcosta*, in its less rugose reticulations, stronger ribs, and straight, instead of curved, umbonal slope. Young specimens resemble *P. (Avicula) emacerata* Hall, but the posterior wing is more expanded, so as to constitute half the surface of the valve.

Pterinea revoluta W. and M.

Plate II. figure 12.

A distinct and well-marked species known only by the impression of the left valve, which is beautifully restored by means of a *gutta percha* cast. This is rotund-quadrate in outline, ventricose, with depressed beak, hinge-line but slightly produced posteriorly. Anterior margin regularly rounded to the ventral side; posterior slightly sinuate below the hinge extremity; greatest dimension from the hinge to the circularly curved ventral side. The surface is marked by seven or eight concentric, lamellose folds or layers of substance, each of which is ornamented by a distinct set of numerous rounded striæ. These are not continuous from fold to fold; neither are they straight, nor strictly radiating from the beak; but they generally exhibit, especially toward their upper ends, a convexity toward the posterior side; in other words, the upper ends of the striæ on each concentric fold are bent forward. The margin of the valve is strongly revolute.

Length from beak to ventral side, .56 inch; length along hinge-line, about .47 inch.

This curious and pretty species recalls *P. planulata* Conrad, and *P. hians* McCoy, from the Amesbury limestone, but the description given above distinguishes it decisively from these and all others known to us.

Pterinea cyrtodontoides W. and M.

Shell of moderate size, oblique; hinge-line equal to greatest width; its extremities rounded, scarcely alate; beaks anterior to the middle. Left valve ventricose, with an incurved beak, an umbonal slope forming an angle of about 65° with the hinge-line, most elevated about midway between the dorsal and ventral margins; anterior margin parallel with umbonal slope, slightly sinuated below the hinge extremity; ventral and posterior margins circularly rounded. Cartilage facet narrow, with apparently a single posterior linear groove, deepest near the hinge extremity, and another short, similar groove anterior to the beak. Surface of cast with feeble concentric striæ.

Length of hinge-line, .66 inch; greatest length of shell, .70 inch; height, .78 inch; depth of left valve, 22 inch; length of anterior end, .25 inch; of posterior end .41 inch; projection of beak, .08 inch.

Differs from *Avicula undata* Hall, by its shorter hinge-line, more projecting beak, and greater ventricosity.

Pterinea striæcosta McChesney, sp. *Ambonychia striæcosta* McChesney. "New Paleozoic Fossils," p. 88. This fine species, to the general form of *Pterinea*, adds a cartilage facet with at least four longitudinal furrows. In one of our specimens the facet is .18 inch wide.

Pterinea neglecta McChesney. sp. "New Paleozoic Fossils," p. 88. Very abundant in casts, often with the two valves united. Exterior seldom seen. This species possessed a very wide cartilage facet which is rarely seen.

Clidophorus Conrad.

Clidophorus m'chesneyanus W. and M.

Plate III. figure 3.

Shell equivalve, with the general aspect of an *Orthonota;* but very slightly widening posteriorly; posterior end symmetrically truncate-rounded above and below, so that the most projecting extremity is on the line midway between the dorsal and ventral sides. The dorsal side is erect, compressed, and the hinge-line is three fourths as long as the shell. The anterior margin is rounded. The beak is very near the anterior end and projects slightly above the hinge. Shell rather ventricose — the umbonal ridge lying above the middle and vanishing in the direction of the posterior extremity. The casts prove the existence of deep pyriform pits for the anterior adductors, which are bounded posteriorly by an elevated margin scarcely possessing the characters of the "clavicular ridge" of Clidophorus. The posterior scars cannot be detected in any of the specimens. In the left valve was a deep cardinal pit, with a stout cardinal tooth in front of it. The surface of casts is marked by two or three deep furrows of growth, with several smaller incremental lines. Restored exteriors present the same character with increased sharpness.

Length, 1.11 inch; greatest width — three fifths the distance from anterior to posterior extremity — .59 inch; length of anterior end, .15 inch; thickness of both valves, .4 inch.

This species differs from *Orthonota* and *Modiolopsis* as defined by McCoy, in the possession of cardinal teeth, and from the first, in its deep anterior muscular impression. It differs from *Orthonota* as restricted by Pictet, in the absence of numerous arcaciform teeth. At the same time it has not the form of *Modiolopsis,* nor its byssiferous sinus and oblique depression; and we are unacquainted with any established genus with which it strictly agrees.

We have dedicated the species to Prof. J. H. McChesney, U. S. Consul at Newcastle-on-Tyne, for his investigations made at the typical locality.

Edmondia de Koninck.

Edmondia Nilesi W. and M.

Plate II. figure 13.

Shell rather small, equivalve, transverse, once and a half as long as wide, subventricose with a prominent umbonal ridge extending to the postero-ventral angle, becoming somewhat acute near the beak, and leaning over toward the hinge, so as to cause the subterminal beaks to project considerably beyond the slightly arched hinge-line and to have their apices twisted forward. The general outline is oval, a little widening posteriorly, and flattened along the dorsal side as far as the middle. Beneath the beaks is an anterior lunette, forming a small notch in the outline. Ventral side gently curved. Shell thin; its exterior nearly smooth, and marked by faint incremental lines. The casts do not enable us to determine the character of the muscular impressions. Greatest width, a little posterior to the middle; greatest thickness, a little anterior to it. In the casts the beak is less terminal than in the shell.

Length, .95 inch; greatest width, .60 inch; greatest thickness of both valves, .40 inch.

We have some hesitancy in making a generic reference of this species, thinking it may be an *Orthonota;* but the apparently edentulous hinge, and the slightly convex dorsal and ventral sides seem to point to *Edmondia.*

Dedicated to W. H. Niles of Cambridge, Mass., the discoverer of the species.

Ambonychia mytiloidea Hall. Wis. Geol. Rep. 1860, p. 2. Casts show concentric folds near the margin. The shell was apparently thick. Resembles *Myalina mytiliformis* Hall, (Pal. N. Y., 100, Pl. xxx. fig. 1,) from the Gray sandstone of the Clinton group.

Conocardium Bronn.

Conocardium niagarense W. and M.

Plate II. figure 14.

Shell small, ventricose, about twice as long as wide, with central beaks and finely costate exterior. The truncation, or boundary of the ribbed portion is posterior to the middle of the shell, and forms, on the posterior side, an angle of 58° with the straight, elongate dorsal side. The form of this end resembles the outside of a salver. The rostrum is produced into a linear extension reaching as far behind the beak as the opposite extremity is in front of it. The beak is incurved, but not perceptibly turned one way or the other. The body of the shell is ornamented by eighteen sharp and delicate ribs, the anterior one forming an angle of 28° with the hinge-line, and the included space being apparently smooth.

Length of shell, about .46 inch; height, .26 inch.

This shell is sometimes found with the two valves united. It is the only species of *Conocardium* known to us in the Niagara group.

It will be perceived that we denominate the rostral extremity the posterior one, contrary to the usage of Pictet, McCoy, and others, but, as we believe, more in accordance with analogies.

PLEUROTOMARIA Defrance.

Pleurotomaria gonopleura W. and M.

Plate III. figure 4.

Shell conical, somewhat flattened on the upper portion of the whorls and on the base. Number of whorls six or seven, enlarging with regularity; suture moderately impressed; keel near the lower side of the whorl, quite prominent; whorl rounded below this, to the suture; above the keel, nearly half way to the suture is another low ridge separated from the first by a concave belt; above this ridge the whorls are flattened convex. Surface marked only by incremental lines which incline backwards in passing from the suture to the keel, and continue in the same direction into the umbilicus, suffering a slight retral inflection in passing the peripheral band.

Height, 1.19 inch; diameter of base, .98 inch; height of last whorl, .50 inch.

This species, though resembling *P. Hoyi* Hall, from the Racine limestone, has two or three more volutions; and has the band on the lower, instead of the upper, angle of the whorls.

Pleurotomaria Halei Hall.? Wis. Rep. 1861, p. 34. Abundant specimens of a *Pleurotomaria* occur, which agree generally with the above species. They differ as follows:—Height equal to transverse diameter, instead of two thirds that diameter; number of volutions five or six instead of three or four; number of revolving ridges on the upper side of the volution five or six, instead of ten or twelve. The periphery, moreover, can hardly be said to be sub-angulated.

To Hall's description it may be added, that the under side of the body whorl is marked by about thirteen wavy, revolving ridges, alternately larger and smaller, intersected by transverse striæ emerging from the umbilicus. It resembles *P. decussata* Sandberger, from the *stringocephalenkalk* of Nassau.

We are in possession of the casts of the umbilical cavity of a very large *Pleurotomaria* which may belong to this species. The revolving ridges rise obliquely from the umbilical cavity, and are intercepted nearly at right angles by a set of less numerous ridges, also rising from the umbilicus, and curving in the opposite direction. Some of these casts show that the umbilical cavity exposed five whorls. The diameter of the base of the largest individual must have been two and a half inches. This individual was reversed, or sinistral. It is not unlikely that the great size of the umbilicus in these casts, and the interrupted character of the ridges emerging from it, and perhaps also the great size of the specimens, give indications of an undescribed species.

Pleurotomaria Hoyi Hall. Wis. Geol. Rep. 1861, p. 35. No flattening appears on the lower side of any of the volutions of our specimens.

Pleurotomaria sigaretoïdes W. and M.

Plate III. figure 5.

Shell small, depressed-conical, oblique, sinistral (in our single specimen), consisting of three or four rapidly enlarging whorls. The whorls are flattened on the exterior, leaving a linear suture. The last whorl is two and a half times as broad on the flattened exterior as the penultimate whorl, sharply angulated at the periphery, which forms the outer boundary of the flat, or shallow funnel-shaped base. It is supposed that this angle is the place of the band, since the surface of the body whorl shows numerous transverse lines, curving retrally from the suture to this peripheral angle. The rapid increase of the whorls throws the apex much nearer to one side than the other.

Height, 30 inch; height of body whorl, .18 inch; diameter of base, .44 inch; apical angle, 76°.

Platyceras (Conrad) Hall.

Platyceras campanulatum W. and M.

Plate II. figure 16.

Whorls three or four, in contact; spire scarcely elevated above the last volution; last volution greatly enlarged, with a nearly circular section, an angulated periphery and trumpet-shaped, circular aperture. Columella none; umbilicus minute; lip not modified by the penultimate whorl. Peripheral ridge in the middle of the whorl or a little above. Surface marked by extremely faint longitudinal striæ, and by remote, obscure, transverse ridges, not retroflected in passing the periphery.

This species seems to be the representative of *Platyostoma niagarense* Hall. It is inferior in size to full-grown specimens of that species, and differs from it in the possession of an umbilicus, and in the completeness of its peristome. It is to be observed, however, that the entire peristome is possessed by many specimens from Waldron, Indiana, that have been referred to *Platyostoma niagarense;* and that the two genera run inseparably together. Should we retain but one of these generic names, *Platyceras* has the prior claim.

Holopea Hall.

Holopea niagarensis W. and M.

Plate II. figure 18.

Shell small, consisting of four or five very convex whorls in a moderately elevated spire having an apical angle of 58°; the last whorl more rapidly enlarged than the preceding, rounded below, and apparently excavated into an umbilicus. Suture deeply impressed, each whorl being almost completely above the level of the preceding one. No surface-markings visible on casts.

Height, .25. inch; diameter of last whorl, .20 inch.

Holopea chicagoënsis W. and M.

Plate II. figure 18.

Shell small, consisting of five or six moderately convex whorls in a sub-elevated spire, having an apical angle of about 42°; body whorl proportionally higher, but not more enlarged than the preceding. The outer side of the whorls is somewhat flattened, becoming rapidly incurved in the upper part, toward the suture; whorls apparently overlapping. Base of last whorl rounded into a minute umbilicus; transverse section of whorl nearly circular. Surface of casts smooth.

Height, .35 inch; diameter of last whorl, .25 inch.

These two species of *Holopea* — existing only in the form of casts — it is impossible to distinguish certainly from *Cyclonema*, though that genus is said to be always exumbilicate.

They are, however, quite distinct specifically from anything at present known to us in the upper silurian.

Loxonema subulata Conrad (*Murchisonia subulata* Hall). No decisive characters separate our forms from the above species of the Clinton group. The number of volutions is nine or ten. Indications of sigmoid incremental lines, without the faintest trace of a peripheral band or apertural slit, induce us to refer our specimens to *Loxonema*, as was originally done by Conrad with the New York specimens. It differs from its foreign analogue, *Loxonema sinuosa* Sowerby, by feebler transverse striæ and a deeper suture, distinguishing it from *Holopella*. This species is quoted from the Niagara group of Canada West. Geol. of Canada, p. 326.

Subulites Conrad.

Subulites brevis W. and M.

Plate II. figure 19.

A species apparently referable to this genus is evidently distinct from any known form belonging to this age. Aperture unknown; number of whorls at least five or six, rather rapidly tapering, flattened on the exterior, widely overlapping, attenuated to a sharp edge on the upper side, producing a shallow linear suture which is also very oblique. Transverse section of whorl narrowly crescentic. No surface characters imprinted upon the casts. This species, in robustness and number of whorls, is intermediate between *S. elongatus* and *S. ventricosus*. The apical portion in all of our numerous specimens is distinctly bent to one side.

Bellerophon Montfort. Bucania Hall.

Bellerophon (Bucania) perforatus W. and M.

Plate III. figure 7.

Shell large, sub-discoid, with about four whorls moderately impressed, and an umbilical cavity exposing all the volutions. Aperture suddenly and broadly expanded, with the lip almost reflexed. Transverse section of whorl circular, with an indentation on the ventral side. Dorsum of last whorl with a low carina on which are elevated a series of elongated nodes becoming somewhat continuous near the aperture — the length of the nodes generally about equal to the distance between them. These are visible on the cast, which also imperfectly preserves some longitudinal markings. The latter, near the aperture, are raised bands with intervening spaces of equal width, and some indications of a general longitudinally striated surface. No nodes exist on the young shell. Exterior of shell marked by numerous sharp, abruptly raised longitudinal ridges, which increase rapidly by implantation in the vicinity of the trumpet-shaped aperture. The nodes of the shell appear, near the aperture, to have been completely perforated, — a circumstance which seems to be only an exaggerated condition of the nodes, as the latter are but apertural modifications of the continuous carina.

Transverse diameter of aperture at least 2.56 inches; transverse diameter of whorl, one third of an inch back from the margin of the aperture, 1.58 inch. — one inch back, 1.42 inch.

This may be the *Bucania pervoluta*, McChesney, though that is described as below medium size; and no mention is made of the very conspicuous dorsal nodes. McChesney has also described *B. chicagoënsis* from the same quarries, but he expressly states that the cast is destitute of a carina. Our species may also be compared with *B. (Bucania) angustata* Hall, as figured in the Geology of Canada, p. 344. There is no comparison, however, between the apertures or dorsal characters of the two.

Orthoceras Scammoni McChesney. New Paleozoic Fossils, p. 92. Specimens unusually well preserved. We may add to the characters given by McChesney, the following: The siphon is .52 inch in diameter, at a place where the shell has a diameter of 1.77 inch. In the same specimen, at the distance of four inches, the siphon is .5 inch in diameter, and the shell has become 1.38 inch. The siphon tapers less rapidly than the shell, and is about one third the diameter of the shell. In the same specimen the diameter of the larger end is 2.2 inches, being the largest specimen seen. Nine and a half inches from here the diameter has diminished to one inch. The distances of four successive septa, where the mean diameter of the shell is 1.4 inch, are .34, .45, .41, .40 — the mean being .40. Striæ of growth two and a half to three in the space of one tenth of an inch.

This species closely represents *O. cancellatum* Hall, but we have not been able to detect any longitudinal striæ between the ridges.

Orthoceras nodocostum McChesney. New Pal. Fossils, p. 94. Our specimens enable us to complete McChesney's description.

Shell very gradually tapering; annulated by a raised rounded ring corresponding to each chamber, and situated a little in front of the middle of the chamber. Intervals between the rings regularly concave. Septa rather deeply concave, crossing the shell with a deviation of three or four degrees from a right angle; their distance asunder being one third the diameter of the shell. No annular striæ can be seen in our specimens. The longitudinal ridges are barely discernible on the shell, and leave no trace upon the cast. The siphon is cylindrical, and about one fourth the diameter of the shell.

The distances apart of four successive septa, in a region where the mean diameter is .65 inch, are .20, .22, .22, .21, giving a mean distance of .21 inch.

The absence of concentric striæ, and the presence of faint longitudinal ridges, distinguish this species from *O. undulatum* Hisinger.

Orthoceras Laphami McChesney, New Pal. Foss. p. 91.

GOMPHOCERAS Sowerby.

Gomphoceras Marcyæ W. and M.

Plate III. figure 8.

Shell of moderate size, perfectly straight. The outer chamber, in connection with the penultimate chamber, gives an outline which is neatly and symmetrically elliptic, with a little flattening at each end. That portion of the shell between the penultimate chamber and the apex is gradually tapering. Transverse section elliptic, with transverse axis to dorso-ventral as 27 to 29 or 30. Apertural extremity constricted in a regularly increasing ratio to the ventral lobe of the aperture, beyond which the constriction proceeds on the sides, in the same manner as far as the lateral lobes of the aperture. The aperture is trisinuate; the two lateral sinuses are situated a little back of the central axis, and are separated from each other by a transverse oral axis, equal to one half the greatest transverse diameter of the shell. The ventral sinus projects nearly as far as the most prominent portion of the shell on the ventral side; and is bounded laterally by the two projecting lips of the aperture. The siphon is of medium size, strongly moniliform, situated on the greater axis, one eighth that axis or less, from the ventral side. The septa are deep, regularly concave; the penultimate chamber is one sixth the depth of the chamber of habitation. Surface of casts marked by numerous incremental ridges, which are deeply sinuate on the ventral side.

Length of last two chambers, 1.6 inch; greatest transverse diameter, 1.09; greatest dorso-ventral diameter, 1.16; depth of penultimate chamber, .20; dorso-ventral axis of the aperture, .84; transverse axis, .60; diameter of siphon, .09; distance from ventral side, .16.; concavity of penultimate chamber, .18.

This unique and elegant, and rather abundant species is amply distinct from anything known to us. There is indeed no other with which it can be compared, though it approaches nearest to *Gomphoceras pyriforme* Sowerby.

Lituites Breynius.

Lituites Hercules W. and M.

Plate III. figure 9.

Shell very large, apparently forming less than a complete whorl in any of the specimens seen. Dorsum and sides flattened-convex — the latter less flattened than the dorsum. Septa moderately concave, plane, much flatter in the middle than around the margins; siphon rather small, central. Greatest transverse diameter three fourths the distance from the dorsal to the ventral side, causing the lateral surfaces to approximate dorsally.

Surface ornamented only by encircling striæ which at intervals aggregate into irregular undulations. The striæ curve backwards on the sides and make a further deep retral sinus across the dorsum.

Dorso-ventral diameter, 4.25 inches; transverse diameter, 4.12; diameter of siphon, .22; depth of dorsal sinus of the striæ, about one inch. The diameter of the shell from the mouth to the opposite side was from seven to nine inches.

One of our specimens is an impression of the shell in the rock. This shows that the apex of the whorl presented an obtuse termination more than an inch in diameter.

Cyrtoceras Fosteri Hall, (Wis. Rep. 1861, p. 41). The specimens in our collection enable us to add to Prof. Hall's description the following characters: Shell rather more rapidly expanding toward the aperture, which is sinuate on the dorsal side. The exterior is marked by incremental lines, which, on the dorsum, are correspondingly sinuate. The two diameters of the aperture in one of our specimens are 1.22 and 1.5 inch; depth of the last chamber, measured on the side, 1.12; depth of the apertural sinus, .18. Siphon cylindrical, .07 inch in diameter, where the septa are at the same distance apart.

Gyroceras H. de Meyer.

Gyroceras Bannisteri W. and M.

Shell consisting of about one and a half whorls, barely in contact, gradually increasing in diameter; transverse section nearly circular; surface ornamented by encircling convex ridges which extend quite around the shell, crossing the ventral side at right angles, thence arching backwards to the dorsal side, where the corresponding branches meet in a broadly rounded angle of about 100°. The distance from the summit of one ridge to that of the next, measured on the dorsum, varies from one third the transverse diameter of the whorl, to considerably less. The space between the ridges is nearly flat, and in the cast — but not on the shell — discloses indications of two low, barely perceptible ridges. The last chamber seems to be entirely destitute of surface ornaments, except incremental lines, which are sinuate dorsally, to correspond with the ridges. There are indications that the aperture was correspondingly sinuate. The position of the siphon has not been observed, but a feeble depressed line or shallow furrow runs along the back of the cast, visible between the ridges, and creating a suspicion that the siphon is in close proximity.

Dorso-ventral diameter, .78 inch at a place where the transverse diameter is .73 inch; distance between the ridges on the dorsum, at the same place, .25 inch. In other specimens the ridges are more approximated.

This species differs from *Gyroceras (Lituites) americanum* Billings, in not being flattened on the back, and in the course of the annulations. It differs from *Lituites giganteus* Sowerby, in having the annulations extend quite across the back without any diminution in size.

Named in recognition of aid received from Henry Bannister, a zealous and promising young geologist of Evanston, Illinois.

Lichas Dalman.

Lichas pugnax W. and M.

Plate III. figure 10.

Body large, outlines unknown. Glabella somewhat parabolic in contour, prominent, with a middle lobe and two lateral ones on each side. Middle lobe consisting of two regions, the anterior of which has a triangularly rounded base, and in the centre is extremely prominent, the front margin descending precipitously to the border; the posterior region is depressed and cuneately produced backward between the lateral lobes, diminishing in the narrowest part to one fifth the greatest transverse diameter of the anterior region, and then widening behind the approximated ends of the lateral lobes. The lateral lobes are oblong-elliptic, slightly flattened on the outer side by the eyes, less prominent than the middle lobe and separated from it by deep valleys; these lobes are twice as long as broad, and their longitudinal axes lie at an angle of 36° with the axis of the middle lobe. The ocular lobes are smaller and more depressed than the last, and lie against their outer sides a little posterior to their middle, being deeply separated from them. The border is thick and narrow, regularly curving around the middle lobe of the glabella, and is not produced in front into a proboscis. Occipital ring very prominent and broad; furrow deep. All parts of the glabella are covered by a granular crust.

The thorax is imperfectly known. It appears from some specimens that the axis is prominent, and from numerous others that the lateral lobes are broadly expanded and imperfectly articulated, though the crust covering the pleuræ is deeply furrowed between the joints as well as along the middle of each pleura. Some of the articulations, undoubtedly posterior ones, become very broad and flat. Every portion of the thorax seems to have been covered with a separable, coarsely and unequally granulated crust, the granules or eminences of which are directed backwards, as in other species of the genus. The basis of the crust is marked by irregularly wavy, somewhat continuous, imbricated furrows, which seem to run nearly parallel with the general outline of the body.

The pygidium is also imperfectly known. It consists of at least three joints. The axis is moderately elevated anteriorly; the first two segments are narrow, the third much wider, and its depressed and narrowed posterior portion extends apparently to the caudal extremity. The flattened and expanded pleuræ are surmounted each by a pair of broad, elongated, obtusely terminated, pad-like elevations, which terminate much short of the tips of the pleuræ. In two large specimens these elevations are separated from each other, and from contiguous pairs, by an intervening flat area. The basis of the granular crust is marked, as in the thorax, by concentric imbricating wrinkles. Characters of the margin unknown.

Length of cephalic shield to the collar, 1.8 inch; greatest width of anterior region of middle lobe, 1.0 inch; length of lateral lobe, 1.0; width of lateral lobe of thorax, more than two inches; length of pygidium, more than three inches. These parts may belong to different individuals.

We at first imagined the conspicuous and unique fragments of this large species to belong to *L. Nereus* Hall, which, in a general way, it strongly resembles. It may be distinguished by the absence of a "proboscis," and the want of articulations in the peripheral area of the caudal shield. A pygidium, with a similar flat inarticulated flap, is seen in *Lichas canadensis* Logan, (Can. Rep. 1844, p. 54).

Lichas decipiens W. and M.

Plate III. figure 11.

Pygidium semi-elliptic, of three articulations, with a prominent axis and a flat border. Two anterior joints of axis, narrow; posterior consisting of an anterior narrower portion and a posterior depressed portion, rapidly subsiding to a level with the lateral lobes, and tapering to a point before attaining the caudal extremity. The ribs are broad, flattened, expanding, divided by a median groove, and terminating in short free points. The anterior rib is nearly transverse at its origin, and distinctly curves backward. The second makes an angle of 45° with the axis and is less curved. The third is straight, and its posterior lobe or moiety is parallel with the axis, meeting the corresponding moiety of the posterior rib of the opposite side. The surface is densely granulated.

Length of pygidium, .5 inch; width, .6 inch.

Bronteus Goldfuss.

Bronteus occasus W. and M.

Plate III. figure 12.

Pygidium with the axis consisting of two articulations. The limb slopes laterally and posteriorly, and is marked by seven equal ridges radiating on each side from the axis, and one additional on the median line, all becoming confluent around the border. These ridges, or rays, exhibit but very little curvature. The median (or posterior) ridge is nearly twice as broad as the others; the extreme ridges on the right and left are at right angles with the axis. The general outline is parabolic. Neither striæ nor granulations are apparent.

Length, .48 inch; breadth, .62; length of axis, .13; breadth of axis, .23 inch.

Several small pygidia in our collection, very well preserved, appear to be distinct from any described species known to us. They differ from *B. flabellifer* Goldf. which has been doubtfully identified in Canada, by their straight ribs, not reaching the margin, and by the absence of striæ and granulations. The species is quite distinct, of course, from *B. niagarensis* Hall (Pal. N. Y., II. 314, pl. lxx. 3).

ILLÆNUS Dalman. BUMASTUS Murchison.

Illænus (Bumastus) worthenanus W. and M.

Plate III. figure 13.

Head elevated, greatly inflated, the glabella closely imitating the superior portions of the human cranium from the middle of the forehead over to the lamboidal suture. The lateral lobes are separated from the glabella by shallow furrows which arise from pits on the antero-lateral aspects, a little above the border, and arch upwards, backwards, and downwards nearly in a circular arc of 160°. The eyes are small, superficially elongate-elliptic, bent over the most prominent portion of the lateral lobes in such position as to look exactly at right angles to the vertical plane passing longitudinally through the middle of the animal. Their position is greatly posterior to, and a little below, the middle of the head. The facial suture starts in the border, below the antero-lateral pit, rises with slight curvature, at an angle of 45° to the anterior extremity of the eye, and thence descends rapidly to the posterior border. The fixed cheek has thus a lunate form. The movable cheek is limited in extent, its width being about equal to the length of the eye; it extends backward as far as the main lobe of the glabella. The occipital ring is extremely arched, giving the head a truncate appearance posteriorly.

In young specimens the glabella is relatively more depressed,—the eye being half way up; the eye itself is more prominent, with a sub-ocular furrow.

The hypostome, in a young specimen, is nearly as convex as the glabella. It has the form of a pentagon with the two sides opposite the base rounded and coalesced into a semicircle,—the curved side of the figure being anterior, the base posterior and transverse to the animal's body. The two sides adjacent to the base are deeply isolated from the central area by furrows which begin at the lateral angles of the pentagon and extend to the base, in close proximity to the basal angles. The thorax is unknown.

The pygidium is the figure included in the arcs of two circles, the anterior of which is of greater radius, and embraces about 60°—the posterior embracing about 160.° A belt around the margin is somewhat depressed, but no trace of trilobation is apparent.

No portion of the test is preserved in any of our numerous specimens; and the casts do not exhibit any traces of superficial ornamentation. The head of the largest individual is 1.9 inches long, 2.2 broad, and 1.4 high. The narrowest part of the glabella, which is between the eyes, is 1.15 inches across, and the widest part—the front—1.45 inches across, the width next the collar being very nearly the same.

This striking species might, on casual comparison, be referred to *Bumastus barriensis* Murchison, but on extended consideration we have been induced to regard it as decidedly distinct from the types of that species. On the side view of the head the anterior portion is more depressed; the eye is below the middle instead of above it; it is horizontal instead of oblique; and the facial suture, instead of ascending almost vertically, rises at an angle of 45°. On the view from above, the head is relatively longer and narrower, and the furrows isolating the glabella much more distinct. Moreover, the pygidium of *B. barriensis (aut rectius barrensis)* is more than a semicircle,—in our species considerably less; it is also much more depressed, and its border is flattened.

We hesitate to insist upon these distinctions after the foreign species has been recognized in this group, in New York, by Prof. Hall. But without expressing any opinion of that identification we may say that the head of our species is much narrower relatively than that figured by Hall, and the glabella has a greater development posterior to the line of the eyes. Some of the pygidia of Hall's species greatly resemble ours,—*e. g.* Plate 66, fig. 2, Pal. N. Y., Vol. II. This species should also be compared with *Illænus imperator* Hall, (Wis. Geol. Rep. 1861, p. 49,) from the Racine limestone.

Acidaspis Murchison.

Acidaspis Ida W. and M.

Plate III. figure 13.

Head more than twice as broad as long, transversely subelliptic in outline, very tumid. Glabella consisting of a median body and three lateral lobes on each side. The median body is twice as long as broad, and narrows somewhat in front of the anterior lateral lobes. It rises in a steep arch anteriorly and posteriorly, being somewhat flattened in the middle. A slight protuberance is generally visible in the middle between the anterior lateral lobes. The median body is separated from the lateral lobes by shallow "false furrows," uniting the extremities of the lateral furrows which sink into deep pits between the lateral lobes. The dorsal furrow is extremely shallow and indistinct, so that the lateral lobes are nearly confluent with the fixed cheeks. The middle pair of these lobes are about twice the size of the others; and the anterior are smaller than the posterior. Occipital furrow deep, its lateral bifurcations sinking into deep pits and isolating the posterior lateral lobes. Occipital ring with a pair of slender, slightly diverging spines, gently curved downward toward the extremity, and having a length of about one inch. Between the bases of the spines is a small tubercle which, in good specimens, is seen to become a short erect spine.

The fixed cheek is convex, somewhat pyriform in outline.

The ocular fillet is well defined along the antero-lateral border of the fixed cheek as far as the eye, which is situated upon a slender, diverging peduncle, about three tenths of an inch high, arising opposite the middle of the cheek.

The movable cheek is broadly crescentiform, of medium size, about as broad as the main lobe of the glabella, projecting forward a little further than the frontal border. Its plane in the broadest part makes, with a vertical plane through the axis of the animal, an inferior angle of about 35°, but anteriorly to this the border is turned upwards, giving a concave upper surface to that part of the cheek. The anterior border is thickened and ornamented with numerous small tubercles arranged at regular distances; the posterior angle is drawn out, and terminates in a slender spine about one inch in length and standing at an angle of 55° with the axis of the animal. The inner side of the base of the spine is continued so far as to deeply indent the posterior border.

The entire surface, except the occipital ring, is covered with granules of unequal size.

Nothing is known of the other parts of the animal, except that a fragment, probably the border of the pygidium, is armed with short, stout spines.

Transverse diameter of cephalic shield (in a straight line), 1.65 inches; longitudinal diameter, .87; width of median body of the glabella, .46; width of fixed cheek, .25; width of movable cheek, .31; middle of glabella elevated above outer border of movable cheeks, .36 inch.

We are in possession of over a dozen cephalic shields of this species, and they all agree to a remarkable extent.

This fine species is in no danger of being confounded with any other American form. It has close analogues, however, in *A. vesiculosa* Beyrich (Barrande, *Silur. Syst.* p. 715, Pl. 38, figs. 13–21), and *A. Verneuilli*, (Id. Pl. 38, figs. 1–9). The occipital and genal spines, nevertheless, are longer, the ocular peduncle is more elevated and more cylindrical, (in this resembling *A. mira*,) the lateral lobes are more confluent with the cheeks; the movable cheeks are more depressed, and the whole head is transversely more elongate.

Besides the foregoing species in our collection from this interesting locality, the following described species have not been met with by us.

Bucania chicagoënsis McChesney, New Paleozoic Fossils,					p. 69.
" *crassolaris*	"	"	"	"	p. 91.
" *pervoluta*	"	"	"	"	p. 91.
Orthoceras camcolare	"	"	"	"	p. 93.
" *striælineatum*	"	"	"	"	p. 94.

Besides the organic remains already enumerated, we are in possession of a few others in a condition too imperfect for determination; among which may be mentioned specimens resembling *Strophomena* and *Naticopsis*; a cluster of eight or ten small, hollow conical, slightly bent tubes, having the appearance of a small Dentalium; also a considerable mass of small stellate and acicular crystal-like bodies, resembling freshly fallen snow-flakes, which may have had an organic origin.

December 22, 1864.

SUPPLEMENTARY NOTE.

About a month after the foregoing paper had been accepted for publication, a pamphlet appeared, from the pen of Professor James Hall, entitled, "*Account of some new or little known Species of Fossils from the Niagara Group.*" This pamphlet, while mainly devoted to fossils from Wisconsin, embraces a notice of twenty-two species of fossils from Illinois, most of which are referred to Bridgeport, and the remainder of which, as I have since learned from examinations kindly permitted by Prof. Hall, come also from that locality. *Of these, only eleven species are quoted from Bridgeport.*[1]

We had been aware, early in December, 1864, that Prof. Hall was at work upon fossils from the Niagara group of Wisconsin; and one of us also informed him that we had just completed a monograph of the fossils of Bridgeport, — a work which had been in progress for about two years. It did not occur to either of us that Prof. Hall's plan, as we understood it, would embrace fossils recognized only at the locality upon which we had been especially engaged. From this misunderstanding has resulted a little synonymy and a little clashing of identifications. A brief review of Prof. Hall's paper seems, consequently, to be called for.

1. The following twelve species are quoted by Prof. Hall from Bridgeport, *and other localities.*

Illænus insignis, *I. armatus*, *Sphærexochus mirus* Beyrich; *Ambonychia Aphæa*, *Avicula undata*, *Avicula emacerata*, Conrad; *Cypricardinia arata*, *Modiolopsis Dictæus*, *Modiolopsis rectus*, *Modiolopsis subalatus*, *Amphicœlia Leidyi*, *Subulites ventricosus.*

[1] The locality of *Pterinea Brisa* Hall, is not given, but it is now known to be from Bridgeport.

2. The following eleven species are quoted only from Bridgeport.

Ichthyocrinus subangularis, Illænus armatus, Acidaspis Danai, Lichas breviceps (?), Ambonychia acutirostris, Pterinea Brisa, Cypricardites (?) quadrilatera, Pleurotomaria Axion, Tremanotus Alpheus, Cyrtoceras Fosteri, Gomphoceras scrinium.

3. The following three species, quoted from Bridgeport, have not yet been seen there by us.

Sphærexochus mirus Beyr., *Modiolopsis Dictæus, Cypricardites (?) quadrilatera.*

4. The following five species, described by us as new, have been identified by Hall with old species.

(*a*) *Ichthyocrinus corbis* W. and M., with *I. subangularis* Hall. Besides the uniform want of angularity of this species, it differs in the perfectly straight bounding lines of the upper and lower sides of the secondary and tertiary radials, which, in *I. subangularis*, are bounded by a double curvature, as in *I. lævis*. We are not in possession of specimens of *I. subangularis* showing the form of the primary radials, but Hall states that "the centres of the upper margins are depressed or emarginate, and their lower margins produced." Scores of specimens of *I. corbis* show a uniform difference in this respect, not to speak of the supposed difference of basal structure.

(*b*) *Lichas pugnax* W. and M., with *L. breviceps?* Hall. The glabella is extremely similar to that of *L. breviceps*, but the pygidium has its axis much narrower anteriorly, and it continually tapers backwards instead of widening. The pluræ also differ.

(*c*) *Pterinea volans* W. and M., with *Avicula emacerata* Conrad. Had Prof. Hall seen the full-grown and perfect specimens in our possession, it is doubtful whether this identification would have been made.

(*d*) *Subulites brevis* W. and M., with *S. ventricosus* Hall. We are not confident in our opinion in this case, but, besides the contrast in proportions, already pointed out, it may be stated that all the specimens in our possession (as well as Prof. Hall's) have the upper part of the spire turned to one side.

5. The following six new genera and species, described by Prof. Hall, have been identified by us with established forms.

(*a*) *Ambonychia Aphæa*, with *A. mytiloidea* Hall. Prof. Hall has cited also *A. acutirostra* Hall, from Bridgeport, and refers to his *Ann. Rep. of Progress of Geol. Surv. of Wisconsin for* 1860. Our copy of that Report (embracing a manuscript copy of a "galley" of matter not bound up with the Report), contains no mention of *A. acutirostra*, or any other Niagara species of that genus, except *A. mytiloidea*. The same is true of the final Report for 1862. Both *A. Aphæa*, and *A. acutirostra* must be extremely near to *A. mytiloidea*, — judging from the descriptions; and it is probable that our identifications, however correct, have embraced both the forms separated by Prof. Hall.

(*b*) *Pterinea brisa* Hall, is undoubtedly *Ambonychia striæcosta* McChesney, or *Pterinea striæcosta* W. and M.

(*c*) *Amphicœlia Leidyi* Hall, is *Ambonychia neglecta* McChesney, or *Pterinea neglecta* W. and M. This new sub-genus (of *Leptodomus*, as supposed) will hardly stand, as our abundant materials have shown that the species on which it is founded possesses a long, broad striated cartilage plate, — an important character not seen by Prof. Hall, and one which, with the cardinal teeth, make it a proper *Pterinea*. At least, it cannot stand as a subgenus of *Leptodomus*. At the same time the general form departs considerably from the type of *Pterinea* (*P. lævis* Goldf.) in being less modified by the anterior and posterior relations. The deep triangular pit beneath the break in each valve, and the duplex, crescentic posterior muscular scar may also be cited as furnishing some grounds for a subgeneric distinction under *Pterinea.* This form may be compared with *Avicula Triton* Salter (Mem. Geol. Surv. Great Brit. Vol. II. Pt. I. Pl. xxiii. fig. 5.)

(*d*) *Pleurotomaria Axion* Hall, has been referred by us to *P. Halei* Hall. We have, however, in our notice, cited the disagreements, while, in the absence of authentic specimens of *P. Halei*, we hesitated to found a new species on the Bridgeport specimens. Having now seen Prof. Hall's types of that species, — an opportunity for which we would again express our obligations, — we are convinced that the separation of the Bridgeport specimens is perfectly proper.

(*e*) *Tremanotus* Hall, is a new subgenus of *Porcellia*, founded upon our *Bellerophon* (*Bucania*) *perforatus.* We may have sufficient evidence of the existence of dorsal perforations in this species. Nevertheless, the perfectly symmetrical enrollment of even the young shell, as well as the enormously expanded aperture (not seen by Hall), would seem to indicate stronger affinities with *Bellerophon* than with *Porcellia.*

6. The following five new species described by us, have been also described by Hall.

Illænus worthenanus W. and M. (*I. insignis* Hall). *Acidaspis Ida* W. and M. (*A. Danai* Hall). *Clidophorus maechesneyanus* W. and M. (*Modiolopsis rectus* Hall). *Bellerophon* (*Bucania*) *perforatus* W. and M. (*Tremanotus Alpheus* Hall). *Gomphoceras Mareyæ* W. and M. (*Gomphoceras scrinium* Hall).

Of these, the following are quoted only from Bridgeport: *Acidaspis Danai, Tremanotus Alpheus, Gomphoceras scrinium.*

Illænus armatus Hall, has been detected among our specimens since the appearance of Prof. Hall's paper.

Cypricardinia arata Hall, has also more recently been observed.

Avicula undata Hall. Specimens have been brought to light which resemble this species, and it is probable that they are the forms referred to it by Hall. They differ, however, in having the beak subterminal, and the posterior wing not isolated from the body of the shell and not extending as far back as the most projecting part. The right valve has two posterior, linear, diverging teeth, which terminate abruptly three fifths the distance from the beak to the cardinal extremity. We should feel inclined to separate these forms from *A. undata* Hall. For the present we designate them as *Pterinea undata* Hall, sp.

Modiolopsis subalata? Hall. We adopt nearly the same observations in reference to certain other forms, which probably are the ones referred by Hall to *Modiolopsis subalata.* Our specimens, however, have, in the right valve, two linear, posterior teeth, and two short lamelliform anterior teeth. The size of the shell is also more than twice that of the types of the species. It seems to possess the characters of a true *Pterinea.* The left valve is much more ventricose, and shows distinctly a strong arcuation of the body, which is less visible in the thinner right valve. Casts of both valves show a few obscure, remote radiating ridges on the anterior slope.

The following new species have also been brought to light by recent work in the quarry: —

Megistocrinus necis W. and M.

Plate II. figure 6.

Body of medium size, pentangularly ovoid, tapering below and contracted toward the bases of the arms, giving the greatest diameter a little above the middle; flattened along the interradial spaces, causing the rays to occupy five conspicuous angles. The inter-brachial spaces are also flattened. Basals rather small, hexagonal. First radials the largest plates of the body, hexagonal or heptagonal, one third higher than wide, the lower lateral sides much the longest. Second radials smaller, hexagonal, similar in form to the first radials; third radials heptagonal, in some specimens nearly twice as long as wide, supporting on its two short upper sides a pair of hexagonal supraradials, above each of which is a second. Regular interradials about ten; the first a little smaller than the first radial, hexagonal, approximately equilateral, surmounted by a pair of smaller plates, and these by a pair still smaller, the others diminishing similarly in size upwards. First azygos interradial heptagonal, a little smaller than the antero-lateral first radials, supporting three variable plates in the second series, of which the middle one is much the smallest. The remaining ones gradually smaller, amounting apparently to twenty or more in number.

The forms and arrangement of the plates in this species are quite similar to those of *M. Christyi* Hall sp. The bifurcation of the rays, however, is considerably lower. The form of the cup, moreover, is very different, being somewhat obpyramidal below, instead of urn-shaped, while it is also much contracted above. The angulations along the rays modify the form of the cup, and are not to be compared with the small threadlike ridges occupying the same position in the Waldron species. The specimens show constant characters.

Megistocrinus infelix W. and M.

Plate II. figure 7.

Body of moderate size, urn-shaped, having a rounded base, but slightly diverging sides, and no constriction below the arm bases, which are somewhat prominent. Raised ridges extend from the basals over the radials, supraradials, and brachials. Basals rather small, as large as the second radials. Radials rapidly decreasing in size; first radials large, nearly as broad as long, with the upper side the shortest; second radials with the upper and lower sides short; third radials oval, heptagonal. First supraradials regularly hexagonal, two thirds as large as the third radials; second supraradials similar in form, but smaller. Brachials two beneath each arm-base. Arms in ten pairs. Regular interradials about ten or twelve in each interradius; the first, hexagonal, as large as the second radials or larger; above this are two others of the size of the third radials, followed by about three or four pairs decreasing in size. Azygos interradials apparently thirty or more, generally hexagonal in form, with nearly equal sides.

Dome depressed, nearly flat, composed of a large number of plates, with apparently a central proboscis. The dome is marked by ten radiating furrows, increasing in depth and width from the centre to the spaces between the pairs of arms, and extending a short distance down the side of the cup, where they vanish. The azygos furrow is much deeper, and deeply indents the upper part of the azygos side of the cup.

This species has the calycinal form of *M. Christyi* Hall sp., but in that species the bifurcation of the rays takes place at more than two thirds the distance from the stem to the arm bases, while in ours the bifurcation is very little above the mean height of the cup. The marked sulcations between the pairs of arms, especially on the azygos side, — existing both on the exterior and in the cast, — constitute the most marked peculiarities of our species so far as at present known.

Holocystites sphæricus W. and M.

Body spheroidal, slightly produced on the basal side, composed of about twelve ranges of polygonal plates rather irregularly disposed, and varying both in form and size, each plate apparently being indented in the middle.

The only specimen of this cystidean in our possession, is a mould of a portion of the exterior, which, when first discovered, was nearly a hollow hemisphere. Its generic relations are not satisfactorily shown, but the great number of ranges of plates seems to ally it to *Holocystites*, — a genus so abundantly represented in the neighboring State of Wisconsin, while the globoid form distinguishes it from any of the species recently described by Prof. Hall.

Conocardium ornatum W. and M.

Plate II. figure 15.

Shell small, very ventricose; beak a little nearest the anterior end, projecting beyond the hinge line and greatly incurved; surface arching from the beak to the ventral side in nearly the form of a semicircle. The truncation, or separation of the rostrate slope from the anterior aspect of the shell forms a posterior angle of about 75° with the cardinal side, and an anterior angle of about 55° with the plane separating the two valves. This truncated plane rises into a crest or elevated rib on the surface of the valve, a little anterior to which and forming an angle of about 20° with it, is another, double-crested, but feebler rib. The remainder of the surface is marked by regular radiating raised striæ. Decussating these and the ribs is a set of numerous sharp raised concentric striæ stronger than the radial ones, the two sets producing a beautifully cancellated surface. The concentric striæ extend over the rostrate slope of the valve, but become there feebler, more crowded, and less rigid.

Length of the shell, .41; dorso-ventral diameter, .30; thickness through both valves, .32; distance from beak to anterior end, .16; to rostrate extremity, .25 inch.

Porcellia senex W. and M.

Plate III. figure 6.

Shell small, consisting of one and a half or two very rapidly enlarging, detached whorls, which are somewhat oblique in the young, but afterwards continue very nearly in one plane. Toward the aperture the shell is flattened and sub-nodulous on the dorsum, — the nodes consisting of a larger and a smaller, alternating with each other in a line along the middle of the flattened surface. The angle by which the dorsal surface unites with the upper side of the whorl is rounded; the other angle is considerably sharper. The aperture is not expanded, but presents a deep sinus extending across the dorsal side. Apex of spire depressed much below the level of the upper side of the outer whorl.

Greatest diameter of shell, .83; transverse diameter of whorl at aperture, .36; the same one inch back, .22; dorso-ventral diameter at aperture, .30; depth of sinus, .22 inch.

The total number of species thus far known from the locality is eighty-two. Of these thirty-nine have been described by us, thirty-nine by others, and four are not specifically determined. There are, besides, three others referred by Hall to the locality, but not seen by us.

NOTE. We are authorized by Prof. Hall to state that he relinquishes all claims upon our two species, following, which were published by him after our paper had been read, viz: *Gomphoceras Marcyæ*, and *Acidaspis Ida*. A similar announcement is to be made in a postscript to his paper, on the appearance of the completed Report of the Regents of the University of the State of New York, vol. xviii.

EXPLANATION OF PLATE II.

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Fig. 1.—CLADOPORA LICHENOIDES W. and M. 84
View of a portion of a frond.
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1*b*, *b*. Stumps of other branches broken off.
Fig. 2.—CLADOPORA VERTICILLATA W. and M. 84
View of one of the verticils.
1*a*. Place of supposed accessory stem.
Fig. 3.—ISCHADITES TESSELLATUS W. and M. 85
Fig. 4.—ACTINOCRINUS OBPYRAMIDALIS W. and M. 87
4*a*. Base of left postero-lateral ray.
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Fig. 5.—MEGISTOCRINUS MARCOUANUS W. and M. 87
View of left side of medium sized specimen.
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6*a*. Dorsal side of a small specimen.
6*b*. Outline of a larger specimen.
Fig. 7.—MEGISTOCRINUS INFELIX W. and M. 110
7*a*. View of right side.
7*b*. View of dome, showing deep sulcation on azygos side.
Fig. 8.—STROPHOMENA MACRA W. and M. 91
8*a*. Exterior of ventral valve.
8*b*. Interior of same valve of a younger specimen.
Fig. 9.—STROPHOMENA NIAGARENSIS W. and M. 92
9*a*. Cast of ventral valve.
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Fig. 10.—STREPTORHYNCHUS HEMIASTER W. and M. 92
10*a*. Exterior of cast of ventral valve.
10*b*. Area, pseudo-deltidium and hinge-line.
Fig. 11.—PENTAMERUS CHICAGOËNSIS W. and M. 94
11*a*. Front view of ventral valve.
11*b*. Side view of the same.
Fig. 12.—PTERINEA REVOLUTA W. and M. 95
Exterior of portion of right valve.
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13*a*. Exterior of right valve.
13*b*. Cast of left valve, showing muscular impression.
13*c*. Hinge-line of cast of a right valve.
Fig. 14.—CONOCARDIUM NIAGARENSE W. and M. 97

Fig. 15.—Conocardium ornatum W. and M. 111
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16*a*. View of upper side.
16*b*. View of aperture.
Fig. 17.—Holopea niagarensis W. and M. 99
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Explanation of Plate III.

Fig. 1.—Pterinea subalata (Hall) W. and M. 109
Cast showing linear posterior and anterior teeth.
Fig. 2.—Pterinea undata (Hall) W. and M. 109
Cast showing linear posterior teeth.
Fig. 3.—Clidophorus mc chesneyanus W. and M. 96
Cast of left valve showing clavicular impression, muscular scar and pallial outline.
Fig. 4.—Pleurotomaria gonopleura W. and M. 97
Exterior of specimen with a defective base.
Fig. 5.—Pleurotomaria sigaretoides W. and M. 98
Cast, defective at the aperture.
Fig. 6.—Porcellia senex W. and M. 111
6*a*. View of aperture and spire of a cast.
6*b*. Dorsum of same, showing notch and nodular elevations.
Fig. 7.—Bellerophon (Tremanotus) perforatus W. and M. 100
7*a*. Cast, with apex and a portion of aperture broken away.
7*b*. Portion of exterior of a specimen from near the aperture.
Fig. 8.—Gomphoceras Marcyæ W. and M. 101
8*a*. Left side of a cast, showing the faint encircling furrows, and an outline continuation of the specimen to near the apex, as demonstrated in specimens actually examined.
8*b*. View of the aperture of another specimen.
8*c*. Fragment, showing the obliquely moniliform sub-ventral siphon, and the convexity of the septa.
Fig. 9.—Lituites Hercules W. and M. 101
Cast of a medium-sized specimen, drawn one half the natural size, showing chamber of habitation with faint encircling furrows.
This is not a representation of one of the typical specimens, and there is even some doubt of its specific identity with them.
Fig. 10.—Lichas pugnax W. and M. 102
10*a*. Cast of a cephalic shield.
10*b*. Side view of the same.
10*c*. Exterior of a defective pygidium.
Fig. 11.—Lichas decipiens W. and M. 103
Cast of a pygidium.
Fig. 12.—Bronteus occasus W. and M. 104
Cast of pygidium.
Fig. 13.—Acidaspis Ida W. and M. 105
Cast of cephalic shield, with spines restored, as seen in numerous specimens.

IV. *The Anatomy and Physiology of the Vorticellidan Parasite* (Trichodina pediculus, Ehr.) *of Hydra.* *By* Prof. H. James-Clark, A. B., B. S.

Read October 18th, 1865.

There can be no doubt that a large amount of the diversity of opinion in regard to the general and classificatory relations of animals arises from the lack of a correct knowledge of the intimate structure of the subject under controversy. This is especially applicable to the lower forms of life, and above all to the fifth and lowest grand division of animals,—the Protozoa. Theories which are based upon insufficient observations, and a misconception of facts, not only present a distorted view of Nature, but mislead and give a wrong direction to the tendencies and currents of scientific research. The theory of the unicellular nature of Infusoria—so acutely upheld by the arguments of Siebold and Kölliker, and especially by the latter in his papers on the Gregarinidæ[1] and on Actinophrys[2]—had no small influence in blinding the mental vision of subsequent investigators; and long delayed the conclusion, strangely enough too, seemingly favored by Kölliker himself, that it is not essential to the constitution of a *cell* that it should possess a tangible, distinctly differentiated envelope.

At the present day we may safely consider every one of the minutest centres of organic development and action as so many individual cells,—not only potentially, but as essentially so as are any of the most decidedly wall-bound cells of the highest kind of tissue,—and yet not become liable to the accusation of leaning toward a visionary method of investigating or interpreting the phenomena of Nature. It really seems as if the much-abused spirit of Oken is about to have its revenge, and the prophetic vision of that immortal genius is soon to be realized by the eyes of the philosophers of the present day. Happily, among the rising generation of the naturalists of this country, a growing independence of thought and action—too long under the shade of the upas-tree of fictitious authority, and allured by the deceitful and fascinating exterior of superficial, glittering, swift, and hasty generalization—is leading to this result with rapid strides.

Neither the genius of a Spencer nor the incomparable ingenuity and tact of a Tolles are able to increase the availability of the microscope as rapidly as the requirements of scientific progress demand; and if one would see beyond the mere optical image of the instrument, he should, by careful and judicious treatment, train the eye to develop to the requirements of the occasion. It must become to him a sliding-scale of adjustable optical powers. The tutored eye of Ehrenberg saw far more than the microscopes of his earlier days could help him to discern. The truth of this is especially observable in the surpassing naturalness and life-like character of his illustrations, so often superior to the delineations of his more modern compeers. When we have combined the effect of the former with the more accurate details of the latter, we shall then, and not till then, have arrived at an honest representation of animal life, and have laid a firm foundation for a

[1] *Beiträge zur Kenntniss niederer Thiere.* Zeitsch. für Wiss. Zoöl., Bd. I. 1848–49, s. 1.

[2] *Das Sonnenthierchen, Actinophrys sol.* Zeitsch. für Wiss. Zoöl., Bd I. 1848–49, s. 198. In some remarks upon Actinophrys, which I took occasion to make at a meeting of the Boston Society of Natural History, (see Proceedings for September 16, 1863,) I stated that the so-called vacuoles of the Actinophrys (A. Eichhornii) are "*true cells with a distinct wall about them.*" In a new work, (*Mind in Nature; or, The Origin of Life and the Mode of Development of Animals*, New York, 1865,) just issued from the press, I have reiterated this statement, and given still further details of the anatomy and physiology of Actinophrys.

series of deductions and generalizations whose influence shall be felt beyond the brief, flitting period in which they were produced.

That investigation which, although confined within a narrow circle, is the most thorough, and at the same time truthfully recorded, is far more valuable for the future than a course of observations which extends over a larger field, and is carried out on a grander scale, but lacks the element of completeness. A thorough and elaborate study of one single species will carry the possessor of such knowledge immeasurably deeper into the secrets of life, and inconceivably further along the road of progress, than a superficial, lightly tripping survey of the whole kingdom of animals. In the former case, for each newly discovered fact the naturalist takes one step higher on the hill of science, whilst in the latter he is forever trying to get the first foothold in the ascent.

Of all the Protozoa there are none which have so great a claim upon the naturalist's time for investigation as the Vorticellidæ. The want of a precise understanding of their structure led, in the first place, to their being classed with the Zoöphyta, and — simply on account of their similarity in form — among the Hydras. This was the first retrocession. After Ehrenberg had promulgated the opinion that they possessed a distinct intestine, whose two ends approximated each other, we find Van Der Hœven, in the second edition of his "Handbook of Zoölogy," comparing them to the Bryozoa, and avowing his belief that their future place will be among the lowest groups of Mollusca. Here we have a still deeper plunge into the vortex of confusion; not so much however, if at all, to the discredit of the Hollandish naturalist, as to that of those who came after him. The apparent similarity of the organization of the Vorticellidæ to that of the Bryozoa was no small warrant for his suggestion; but, after almost every microscopist of any degree of reliability, who looked at these infusorians, had disproved and denied the presence of the intestine, so elaborately set forth by the Berlin micrographer, and nothing was left but a mere resemblance in outward form to the Bryozoa, that was, to say the least, a very far-fetched comparison when Professor Agassiz homologized them with the Mollusca, declaring that he had satisfied himself of the "propriety of uniting the Vorticellidæ with Bryozoa."

Ere this, too, Lachman (Müll. Archiv. 1856) had shown that the whole group of ciliated Infusoria possessed a conformity of organization altogether unlike that of any other. The profound researches of this early lamented observer left no doubt as to the dissimilarity between the Vorticellidæ and Bryozoa. Here was, at last, a step taken in the right direction; and when this author, in connection with Claparède, published the "Études sur les Infusoires et les Rhizopodes," the climax of proof was attained in the abundance of details presented in that remarkable volume. Among the many questions which are discussed in that work, that of the unicellularity of the Infusoria receives a considerable share of attention; and a decided ground is taken in favor of their *pluricellularity;* not so much, however, on account of their being known to consist of more than one cell, as of the fact of their possessing such a variety of organs and performing so many diverse functions.

The greatest variety of this kind is most elaborately exemplified by the group of Vorticellidæ; but yet it rises, from the lowest of the class, through such insensible grades that the relations of the type of the two extremes are never lost sight of amid the growing complicity of the organization.

Among the many forms which more than usually excite the interest of the observer, there is no one in the whole class of Protozoa that surpasses the allurements of the remarkable creature which forms the subject of the present memoir. This is accounted for by a twofold reason: in the first place, because it possesses such an unlooked-for degree of complication in its organization; and secondly, because it seems to stand intermediate between the two great groups of Ciliata, — the *dexiotropic* on the one hand, and the *læotropic* on the other. The transitional forms in all departments of the animal kingdom are eminently suggestive, but none more so than the genus *Trichodina*. Combining in one animal the typical forms of two groups, and yet so singularly individualistic as to be confounded neither with the one nor with the other, the elaborate solution of the relations of the various members of its organization to each other, and the tracing of their homologies with those of the groups on either side, engage the attention no less deeply, and none the less worthily, than if it were occupied in the investigation of the most profound philosophical problem.

An attempt, therefore, at a full life-history of this animal becomes an effort at something more than a mere specific description without an aim; and whatever apparent triviality of detail there may seem to be in it, the consciousness that no one part of an organization is without relation to some other part leads the author to the opinion that an investigator should never undertake to assume what is of importance and what is not. It is no infrequent occurrence that what, at one time, has been deemed worthy of very slight consideration, becomes, at another, the paramount object in a course of scientific research. Nature is not to be represented in full detail by the broad touches and counterfeiting portraiture of a Vandyck, howsoever striking and suggestive the likeness may be; in order to bear a closer inspection, her image must needs be mapped and copied by the more matter-of-fact hand of the humbler Netherlandish artist.

§ 1. Habitat.

This species (Pl. IV., *Trichodina pediculus* Ehr.) is found in great abundance creeping over the body, and even to the tips of the tentacles, of our common brown and green fresh-water Hydras (*H. fusca and H. viridis* Trembley). Oftentimes it may be seen with the middle of its base applied directly over the centre of a group of nettling organs, the former fitting the latter like a cap, and without seeming to disturb the Hydra in the least.

Notwithstanding the apparent rigidity of the chitinous, uncinate ring of the base, the latter possesses the greatest degree of flexibility, and an unlimited adaptability to whatever surface it may come upon, no matter how uneven it happens to be. The intimate structure of the chitinous ring does not interfere in the least with, but on the contrary appears to assist in, the flexures of the base. The latter is always the point of attachment; and upon this part of the body the animal may be seen, almost at all times, gliding to and fro like a miniature cup (figs. 1, 2), now on the upper side of a Hydra, and then on the lower side. At one moment several individuals are crowded together on the tentacles, and in the next instant scattered along its length from base to tip, and giving to it a singularly irregular, changeable outline. At times the Hydra seems to be strangely knotted, and ungainly in outline; when, upon close examination, we ascertain that it is crowded with a swarm of Keronas, upon several of whose convex backs, one, two, or three Trichodinas are seated, enjoying the pleasure of locomotion, without the effort to produce it. Not unfrequently an individual may be seen to leave its reptant mode of progress and take to the surrounding element. Then it swims, at times very swiftly, either in a fully expanded state, or half expanded (fig. 4), or even shortens its length so much that its body resembles a wheel (fig. 5) rolling on its axis, or turning end for end and performing a series of somersaults with great rapidity. Presently it returns to its more quiet mode of life, sliding spectre-like over the animate surface which forms its principal field of operations. During its act of reptation it revolves very slowly upon its longitudinal axis, as if upon a pivot, and most frequently, if not always, wheels to the right.

§ 2. Specific Relationship.

When looking at perfectly fresh and lively specimens of this infusorian, one can hardly believe, at first, that their deep, cyathiform, dice-box-like bodies (figs. 1, 2) are specifically identical with the straight and broad cylindrical forms which are figured by Ehrenberg and Dujardin, or with the turban-shaped bodies which are illustrated in the papers of Stein and Busch; but when, upon prolonged investigation, we see that the least interference with their freedom of motion causes them to assume a depressed form and a partially retracted margin, we recognize their close resemblance, at least, to those of the above-named authors. The former state represents Nature in reality, the latter exhibits her in a disguised shape. It is therefore with no small degree of reluctance that one concludes to identify the flexible, irregularly funnel-form, conspicuously asymmetrical body of the American Trichodina with the seemingly stiff, precisely outlined, cylindrical or conical figures illustrated in European works; but a careful study of this under various conditions, both in regard to space for movement and the quality of the water, inevitably leads to the conclusion that the European figures represent the creature in an abnormal, or at least a more or less restrained condition; certainly not in a perfectly healthy state.

If a Hydra, upon which some of these animals are living, is transferred to a flat watch-glass, and the water is frequently renewed, there is not the least difficulty in studying this infusorian whilst in its fullest degree of expansion, and even with a magnifying power of at least five hundred diameters. In fact it is absolutely necessary that the body should be fully expanded in order to understand the relation and nature of certain parts of its organism; especially the vestibule and œsophagus, and the contractile vesicle. In a semi-expanded state of the body these parts are confused; and it becomes impossible to ascertain their character with even the least degree of satisfaction. It is on this account that neither the figures of Stein nor those of Busch give the faintest idea of what the anterior region of Trichodina is like; and we actually get a better and truer impression of its character from the almost forgotten illustrations of Ehrenberg, than from the more modern, and what ought to be more correct, delineations of this animal.

§ 3. Form.

The form of the body is like that of a heavy wine-glass (figs. 1, 2, 8, 14) with a very thick and but slightly expanded base. The plane of the margin of the front — *i. e.* the peristome (d^1) — lies parallel with that of the base, or "adherent organ," and nearly at right angles to the axis of the body. The *disc* (c, c^1), or area encompassed by the vibratory crown (b), is deeply depressed, so that the anterior end of the body, not only externally but internally, is truly *cyathiform.* In fully expanded individuals the depression of the disc extends nearly to half the depth (at c) of the body, and occupies at least nine tenths of the diameter of this region. At times the animal suddenly recurves the edge of the cup nearly back to its base, and exposes the bottom of this hollow in a most convincing manner (fig. 6). In partially contracted individuals (fig. 10), the bottom of it becomes elevated, and projects like a boss (*c*) more or less beyond the inrolled vibratile organ (*b*). This is the condition — with the vibratory cilia more or less projecting — of those figured by all observers, and especially by Stein and Busch; and a form which the creature very frequently assumes when in a confined state.

It is an easy matter to see that their natural and accustomed shape is as we have represented these animals, — if one studies them undisturbed, as they creep over the body of a Hydra which is attached to the side of an aquarium. With a Wollaston doublet, magnifying thirty diameters, or even a Tolles triplet, magnifying seventy-five diameters, one may, with great facility, survey, through the glass sides of an aquarium, the whole body of a Hydra, and watch the movements of the Trichodinas which infest it. Under these conditions it is no exaggeration to say that it is very rare to meet with a Trichodina whose disc protrudes — and that only momentarily — beyond the plane of the vibratile crown, but on the contrary it is sunken far below this plane; thus rendering the region about this part of the body singularly transparent, light, and airy. This effect is very much enhanced, moreover, by the excessively transparent, filmy exterior wall (*p*) which projects, very prominently in profile, between the two ends of the body.

The contour of the body behind the spiral, vibratile crown (*b*) is singularly irregular, especially in a transverse direction. A sectional view (fig. 9) presents the form of an irregular circle with various projections, inwardly and outwardly, from its main course. This arises from the fact that the body is fluted and ribbed exteriorly by irregular, longitudinal furrows and projections (fig. 14, *r*, *r*), which extend from one end of it to the other. The ribs (*r*) arise with a broad expanse immediately behind the anterior ciliated margin (d^1), and gradually narrow toward the mid-length, and then more gradually expand to a much less width at the posterior end. At first one is impressed with the idea that they are longitudinal muscles; but, as they are more carefully examined, they do not appear to be anything but mere thickenings and folds of the body-walls.

The principal cause of the one-sidedness of the body is the protrusion of the region (figs. 8, 11, 13, *d*, d^3) about the mouth (*m*) of the vestibule (*v*), transforming the circular outline of the vibratile organ (*b*, b^1) into a broad oval figure, when this ciliated margin is foreshortened (fig. 13) and brought into focus with that part which winds spirally downwards and into (at b^2) the aperture of the vestibule. In the form of the disc, and the circumambient, spiral, vibratory crown, we are reminded rather of Stentor than of the Vorticellidæ; nor would it be amiss to suggest here, that, in this respect, Trichodina stands intermediate between the Vorticellidans and the group (Bursarinæ) to which Stentor belongs.

Owing to the presence of the reproductive organ (*n*), and the so-called "adherent apparatus" (fig. 10, *h*, *i*, *l*, l^1), the expanded circular base is even more conspicuous than the discal end. It most frequently presents itself as a rather abruptly widening, perfectly circular, disciform expansion, whose plane trends transverse to the axis of the body. It varies in form more or less according to the surface over which it is creeping: at one moment sunken (fig. 14) like a cast into a depression of the body of the Hydra, and at the next instant assuming the reverse form (fig. 10), and embracing some projecting group of cnidæ, or as it were wrapped around the parietes of an extremely elongated tentacle. As a farther extension, the base is margined by an annular membrane, or *velum* (*f*, f^1), and a single row of cilia (*g*); both of which serve to heighten its conspicuity, and give to this region of the body the appearance of greater weight and firmness.

§ 4. The Prehensile Organs.

The motory organs appear to be divided into two groups, of which one is very active in character, and the other is comparatively passive and resistant. The members of the former group are the vibratile cilia and *velum*, and those of the latter constitute the "adherent organ."

The vibratory crown. The vibratile cilia occupy two widely separate parts of the body, in one place fulfilling the office of purveyors of food, and in the other acting as organs of locomotion, in the strictest sense. The former are the true prehensile organs, and, with the margin to which they are attached, constitute the so-called "*vibratory crown*" (b, b^1, b^2). This organ lies, in the form of a nearly flat spiral, at the anterior end of the body, and borders the edge of the cup which forms the principal part of the front. It therefore rests on the periphery of the *disc* (c, c^1, c^3), so that a delineation of the one defines the contour of the other. The spiral commences (b^1) at the extreme right of the front, and, sweeping around ventrally and just before the edge of the mouth (m) of the vestibule (v), passes to the extreme left, and thence along the dorsal edge of the cup, whence it passes toward its starting-point on the right, but a little exterior to it, so as to overlap it. Thus far it follows the edge of the cyathiform disc, and forms a distinct border throughout its circumference; but in passing to the termination of its course it runs along the extreme brink of an inclined plane (figs. 11, 12, c^4) which rests on a cornice-like projection that extends obliquely across the body, from the right, slightly backwards, toward the left, as far as the aperture (m) of the vestibule, and then rapidly narrows and becomes blended (fig. 13, d^4) with the body beyond. In fact the vestibule (v) is buried for its major part in this oblique projection, and opens at the widest, or terminal part of the inclined plane which forms the anterior face of the latter. Consequently the vibratory crown, when following the border (d^3) of this plane, passes exterior to, and along the ventral side of the aperture of the vestibule, but, instead of going beyond it, gradually approximates it, and finally entering at its left side, and taking an oblique course toward the right, plunges to its very bottom, in one unbroken, single line (fig. 13, b^2).

In the true Vorticellidæ the disc is a prominently marked organ, and is more or less elevated above the annular peristome; whereas in the Trichodina before us the peristome (d, d^1, d^3, d^4, d^5) is not a closed circle, but is blended with the spiral margin of the disc (c, c^1, c^3, c^4), or rather the *disc*, instead of projecting beyond the rest of the body, is sunken (c, c^1), — invaginated, as it were, — and has a deep cyathiform contour, and its margin is only separated from the peristome (fig. 15, d^1) by the slight furrow (b^3) in which the cilia (b) of the vibratory crown are implanted. This relationship is strikingly exemplified in another way; for when the animal is contracted (fig. 10) and the peristome (d^1, d^2) rolled inwardly, the vibratile row of cilia (b) is not to be found at the bottom of the enclosed space, — as is the case when the like phenomenon occurs in Vorticella, Zoöthamnium, Carchesium, and Epistylis, — but hangs down into that space, like a fringed curtain, from the inrolled edge of the peristome. The distinction between disc and peristome is therefore no more marked than in Stentor, and, in consequence of the relation of the two, the peristome, instead of traversing the ventral side, and forming a complete ring, as in the true Vorticellidæ, descends, with the vibratile organ, to the mouth of the vestibule, and then vanishes in the general surface of the body.

The vibratile cilia (b) of this organ are very long and slender, thread-like bodies which stand in close rank, in a single row. They arise from the bottom of a slight furrow (fig. 15, b^3) which extends along the inner side of the peristome (d^1), from its beginning (b^1) on the right, throughout its first turn (d^5), and thence to its termination (d) at the left margin of the aperture of the vestibule. They usually incline in the direction which leads toward the mouth, and along the margin of the disc, — *i. e.*, throughout the extent of the first turn of the spiral, — and they at the same time spread outwardly as if in continuation of the flare of the cup; but occasionally they incline toward the centre of the depressed disc, and produce a vortex therein by their combined action.

The œsophageal cilia. The vibratile cilia which line the œsophagus (o, o^1) and seem to be continuous with those of the vibratory crown (b) which enter the vestibule, are much more delicate and shorter than they, and although they perform an analogous duty in the preparation of the food before it is finally taken into the general cavity of the body, yet, inasmuch as they are occupied in the more special office of moulding the intussuscepted matter into nutritive pellets, they in all probability are to be looked upon as belonging to a separate system from those of the vibratory organ.

The so-called *bristle of the vestibule* of Vorticellidæ, which was first described as such by Lachman (Müll. Archiv. 1856, s. 348, Taf. XIII. figs. 1–5, *cg*), *is an optical illusion!* It was almost by accident that we were induced to doubt the character of this seemingly definite body. After having successfully followed two rows of cilia from the stem of the rotatory organ into, and to the very bottom of the vestibule of an *Epistylis* (E. galea Ehr.?), it seemed very strange that the "bristle of Lachman" had not been met with, during such a close and searching scrutiny. Recalling its position, as described by Lachman and by Claparède, and as we thought we had seen it on former occasions, it was observed, that, whilst one of the rows of cilia, which had just been traced into the vestibule, occupied its right side, the other row was in the position of the so-called bristle; *i. e.*, it trended along the left side of the vestibule. Occasionally it was noticed that both the right and left rows of cilia had the appearance of single vibratory lashes, and that the left row, where it ran out beyond the aperture of the vestibule, and thence upon the stem of the rotatory organ, had a particularly strong resemblance to a single lash or bristle; especially when the cilia projected toward the eye, so as to foreshorten the whole row. In the latter case it is easy to see how, when the cilia vibrated in regular succession, they would produce the effect of an undulating line. The closest scrutiny, with a Tolles one-eighth of an inch objective and a B ocular, — equalling a magnifying power of 750 diameters, — utterly failed to discover the least trace of anything else which might correspond to the so-called vestibular bristle; and it was therefore fully determined upon that there is no such body existing in the vestibule of the Epistylis. The same observations were also made upon another species of Epistylis (E. grandis Ehr.?), and upon Carchesium (C. polypinum Ehr.), and Vorticella (V. nebulifera Ehr.), and with the same result.

Notwithstanding this forewarning, it was very difficult to dispel the illusion when the vestibular cilia of *Trichodina* were under investigation. If one observes attentively, however, it will be noticed in the first place that what appears to be a single cilium or bristle never projects beyond the *tips* of the cilia which lie outside of the aperture of the vestibule; and secondly, that when the tips of these cilia are followed along with the eye, the row appears to terminate abruptly, and exactly at that point there seems to be the end of a bristle, *i. e.*, the tip of the latter ends just where the line of ciliary points terminates, — *the two are coincident!* Sometimes the point of coincidence is seen opposite the left side of the vestibular aperture, at other times opposite the middle of the same, or considerably to the right of it. Again this point of coincidence appears to run rapidly from left to right, and then back again from right to left, as if the tip of the bristle were sweeping along the row of cilia, and pushing them back in succession. In addition to this it will be noticed that the end of this false bristle varies in thickness from moment to moment, during the shifting of the point of coincidence; and finally it may be remarked that it frequently seems to be broken into a series of dots, or short, irregular pieces. This last feature gives the clue to the mystery. The apparently disjointed pieces of the tip of the false bristle are nothing more nor less than the foreshortened points of the closely approximated, successive cilia, as they project toward the eye during the descent of the row into the vestibule. The point of coincidence mentioned above is the place where the row bends abruptly toward the aperture of the vestibule; and the shifting of this point is the changing of the trend of the ciliary tips. The line of attachment of the cilia is not changeable, and it may be readily traced to the bottom of the vestibule; but the cilia whilst projecting, at various and constantly diversified angles, from their base of attachment, are so disposed that their approximated tips form a frequently varying, undulating line. The reason why the "bristle" sometimes unaccountably disappears during observation, arises from the fact that the cilia have so changed their position that they do not afford a view which presents the appearance of such a body. Usually, however, the cilia are curved transversely to the axis of the vestibule, so that they form as it were a cylinder of juxtaposed hoops or circles; and it is not to be wondered at, therefore, that in almost any position the outline of this cylinder should appear as a single line, or filament. In a view directly into the aperture of the vestibule, the bristle, so-called, is not to be seen, for the very reason that the cylinder is presented endwise, and on this account, too, the vestibule appears to have a double contour, the inner one of these contours being nothing less than the series of curved cilia placed closely side by side, and trending transversely to the axis of the cavity in question. This is a particularly facile observation in Vorticella, and none the less so in Carchesium. Finally, it may be said on this point, — and coming last it is of no less importance than what has preceded, but on the contrary is worthy of the utmost consideration in an optical point of view, — that were the so-called bristle a genuine body, it would be in focus at only one particular adjustment of the lens; whereas we find, that, having obtained what appears to be a clear and definite view of a filament, it does not go out of view by a change of the focus over a considerable extent above or below that horizon. This, one may readily perceive, would be the case in observing the outline of a transparent cylinder; and as the closely approximated, curved cilia form such a cylinder, the outline of the latter is likewise as variable as that of any other similar form.

§ 5. The Locomotive Organs.

The locomotive organs are divided into three quite distinct sets, and appear to have as many diverse offices. They are all situated at the extreme posterior end of the body. Taken in their order, they stand thus: 1st, a veil, or membranous annular margin (f, f^1);

2d, a row of vibratile cilia (g), which lies immediately behind the veil; and 3d, a complex "adherent organ," in the form of a circle of centrifugal hooks (figs. 10, 17, 18, h) and centripetal rays (i) which are firmly attached to the truncate, posterior face of the body.

The *velum* (f, f^1) is merely an excessively thinned margin of the abruptly expanded, truncate, circular base. It has a breadth which is at least one third as great as the length of the vibratile cilia (g), which are attached in a single row immediately behind its basal edge (fig. 17, f^2). The free edge (f^1) of the *velum* is smooth and regularly curved. It is not very difficult to distinguish from the closely set row of cilia (g) just posterior to it. Although these cilia move so uniformly in concert, or in regular succession, as to appear at times like a vibrating, frilled margin (fig. 10), yet, when they are nearly quiet, the veil may be distinctly seen — especially with a one-eighth of an inch objective — as an overlying, separately undulating membrane. With oblique light, at about twenty degrees from direct illumination, the velar edge is very conspicuous, and may be seen to be margined by a thickening (fig. 17) which is easily traced across the whole width of the body, and at a decidedly different focus from that in which the bases of the vibratile cilia underlie it. In a profile view, it may be recognized as an abruptly terminating, marginal, tongue-like projection, vibrating by fits and starts (fig. 11, f), at the periphery of the circular base.

The *basal vibratile cilia* (g) form a complete, symmetrical circle about the truncate, posterior end of the body. They are more delicate, and much longer than those of the anterior, vibratory crown (b), and arise, in a single, closely set row, from a slightly projecting annular ridge which immediately subtends the line of attachment of the *velum*. This annular ridge, as will be seen presently, is the border (figs. 10, 17, l^1) of the adherent organ. Owing to their excessive fineness, the close proximity in which they are set, and the almost uniform succession with which one cilium follows the other in the series of vibrations, this system gives to the unaccustomed eye the impression of an undulating, fringe-like membrane, when it is viewed with only a moderate magnifying power; but with an amplification of five hundred diameters, — if the objective be a good one, — one may trace the cilia to their very bases, with the perfect confidence of not having seen amiss, and at the same time satisfy himself conclusively that they are unequivocally distinct from the veil which lies in front of them. There can be no hesitation, therefore, in pronouncing the veil and the vibratile row of cilia as two distinct and separate systems, with no connection whatever other than a close proximity of attachment to the basal margin of the body, and their similar duties in the process of locomotion.[1]

The *adherent organ* (figs. 10, 17, h, i, l) is a complex apparatus, which altogether forms a thin, circular disc, whose border (l^1) reaches to the margin of the base, or, in other words, to the inner edge or line of attachment (f^2) of the *velum* (f).

About one third of the radius of the adherent organ, at the peripheral margin, is occupied by a *striated, annular membrane* (l, l^1, l^2, l^3, l^4, l^5), which is separable from the rest of the apparatus. It lies in *front* of the centrifugally projecting hooks (h), but closely pressed against them, and extends centripetally (to l^3) as far as their bases. This membrane is possessed of two sets of *striæ*, which radiate from its inner to its outer margin. *One set of striæ* occupy the anterior face (fig. 17, l^1 to l^4), and are comparatively quite coarse (l^2), and in number about ninety-six, *i. e.*, four times the number of the hooks (h) of this organ. They lie wide apart, and are arranged so uniformly that two traverse the interval between every two hooks, and two overlap every hook, where they run to the proximal margin (l^3)

1 See the note on the "*adherent organ*" at the end of this section, p. 124.

of the membrane. In dead or dying specimens, this membrane becomes folded or wrinkled (fig. 16, l^1) transversely, and then these *striæ* (l^2) overlap each other and appear to fork more or less, or seem to be linear processes, divergent from the curved ends of the hooks (h).[1]

The other or *posterior set of striæ* (l^4 to l^5) is much more readily detected than the anterior one, and the *striæ* are about three times as numerous. They are so closely set together that it is a difficult matter to count them, although viewed with a one-eighth of an inch objective. They extend, like those of the anterior set, over the whole breadth of the membrane, and, terminating abruptly at the peripheral margin (l^1, l^4), give to the thickened edge a milled appearance. This milling is, moreover, rendered conspicuous by an incrassated, scalloped border (l^1), in which the striæ (l^2) of the front set terminate.[2] The striated membrane is very flexible, and is frequently made to undulate, apparently, by the successive impacts of the vibrating cilia.

The apparently most important members of the adherent organ are the *hooks* (h). They vary in number from twenty-two to twenty-four, and curve in a direction which is diametrically opposite to the upward coil of the vibratory organ; *i. e.*, they are *læotropic*. They are *separate pieces*, of an £-formed (fig. 18, h, h^3) shape; the upright part of the £ being the *hook* (h) proper, and the horizontal limb (h^3) the base of it. These £'s are arranged in a circle with their horizontal limbs all pointing one way, — *i. e.*, the same as the upright part, or hook, — and nearly or quite touch each other, according to circumstances. A spur-like, slender point (h^2) projects from the horizontal part, in the opposite direction, and is about half as long as the latter. Along this spur and the convex side of the hook a broad, lunate crest (k) arises, and, nearly filling the interval between two succeeding hooks, projects peripherally beyond the tips of the latter. This crest is excessively faint, and not recognizable as a distinct body unless the striated membrane is removed; although it is to be seen when in place, especially where it projects beyond the tip of the hook, and forms with the others a succession of scallops (fig. 17, k), lying in a circle parallel with the margin (l^1) of the striated membrane.

Immediately within the row of hooks a series of *nail-shaped pieces* (i^1, i^2) extends in a circle; and they are arranged in such order that each one lies opposite the horizontal part (h^3) of a hook. The pointed, conical head (i^2) of the nail-shaped piece corresponds in

[1] In the *Proceedings of the Boston Society of Natural History* for November 6, 1850, p. 354, Prof. L. Agassiz makes the following statement in regard to the relation of *Trichodina* to the *Medusæ:* and especially in reference to these apparently forked, radiating striæ, which remind one of the numerous radiating tubes of certain Hydroid Acalephæ. He says, — "*These parasites at times leave the Hydra, and swim free, changing their form in a remarkable degree. In addition to the internal ring, he was able to trace rays going from the hooks to the margin, divided into numerous branches, and also rays proceeding toward the centre from this ring; the margin has a fringed undulating edge, under the tentacles. By feeding them with colors, he was able to see that the internal folds are the margin of a mouth, as in Rhacostoma, so that these parasites on Hydra are diminutive Medusæ. In the egg of Hydra, he had been able to trace all the forms from a segmented yolk to these parasites; the fresh-water Hydra is the* Polypoid *form of Medusæ, while these parasites are the Medusoid form.*"

If this be true, then the whole group of Vorticellidæ (from which no one would for a moment think of separating Trichodina) must be removed to the class of Acalephæ! We must, for our own part, however, unequivocally dissent from this view, since it is quite at variance with our own observations. But again, according to another more recent statement of Prof. Agassiz, in his *Essay on Classification* (Boston, 1857, p. 72; London ed., 1859, p. 108), he has satisfied himself of the "*propriety of uniting the Vorticellidæ with Bryozoa,*" *i. e.*, the group of Vorticellidæ; and consequently the *Acalephan* (*vide* preceding paragraph) *Trichodina* — is Molluscan! From this view, also, we would modestly, but unequivocally dissent; not only as the result of our own investigation, but in accordance with the observations of other very competent authorities. This view would also seem to argue that the Bryozoa — if they do not strictly belong, with Polypi, to the division Radiata, as is insisted upon by other, and eminent authority — are at least a transitional group between Radiata and Mollusca.

[2] The separation of these two sets of *striæ*, or radiating ridges, is an excellent test of the quality of a quarter-inch objective; a one-eighth of an inch lens can do it easily.

position with the point of contact of the bases of two successive hooks, and at the broadest part protrudes sideways between the latter. The tip of the nail-head projects between the point (i^4) of the succeeding nail and the base (h^3) of a hook; the two latter constituting a sort of socket in which the former appears to slide. This would seem to show conclusively that this complicated ring may be enlarged or diminished at the will of the animal.

The faint radiating ridges (i) which occupy the central two thirds of the adherent apparatus are attached one by one to the point (i^4) of the nail-shaped body just mentioned, and at right angles to it. The basal third of these *radii* is easily seen with a one-fourth inch objective, but even a one-eighth does not distinctly trace the pointed end to the centre of this apparatus. Each *radius* (i) and the nail-shaped body (i^1, i^2) seem to form a solid piece, a sort of Greek Γ whose angle is occupied by a *faint membrane*, or web (i^3), which extends from one third to one half the way along the nail, and nearly, or altogether to the end of the tapering radius. This faint membrane appears to fill the whole space between the *radii*, in healthy animals.

In dying specimens the adherent organ readily separates from the body, *en masse;* but shortly afterwards the striated membrane loosens from the circle of hooks; and in a brief space of time the latter becomes disjointed, and each hook detaches from its fellow, but remains for a longer period in conjunction with its corresponding radius and nail-shaped piece.[1]

§ 6. The Digestive System.

This infusorian takes so readily to an indigo diet that the process of collecting food

[1] Various opinions — and all of them at variance with the one promulgated in this paper — have been expressed in regard to the nature of the adherent apparatus, and its motory appendages, the vibratile row of cilia. Siebold (*Zeitsch. für Wissenschaft Zoöl.* Bd. II. s. 367), as the following translation shows, has mistaken the row of vibratile cilia (g) for an *undulating membrane*, and has entirely overlooked the *velum* (f). He says, "*Among the Infusoria, the genus* Trichodina *is endowed with a distinct, undulating membrane, which, applied to the lower margin of the body, in the form of a circle, adheres to, and is supported by, a solid, toothed apparatus, not unlike a watch-wheel. In* Trichodina pediculus *this vibrating border is entire-margined; in* T. mitra . . . . *the free border of this appears to be deeply and delicately fringed.* Trembley, Goeze, O. F. Müller, Carus, Dujardin, *and others, have, in consequence of an optical illusion, considered this undulating membrane in* T. pediculus *as a vibrating-cilia-crown.*"

Stein (*Infusionsthiere*, 1854, s. 176) controverts the assertion of Siebold, and insists that the "undulating membrane" of the latter is a crown of cilia; but yet, as in Siebold's case, the *velum* has entirely escaped his notice. He writes as follows: "*The posterior cilia-crown . . . on account of the very closely set cilia, does certainly readily produce the impression of an undulating membrane margining the rear-body, which not only in* T. mitra, *but also in* T. pediculus, *appears to be denticulately notched; but let one kill the animal with diluted acetic acid or alcohol, and he will separate each single cilium sharply. That the posterior cilia-crown is connected neither with the toothed horn-ring, nor with the annuliform membrane, let one convince himself thereof by crushing the animal, by which one easily separates the entire adherent apparatus, in all its integrity, from the body.*"

Next Busch (*Müll. Archiv.* 1855, s. 358) appears in the field of controversy, and, commenting upon the observations of the two foregoing authors, compromises their views by uniting the vibratile cilia to the edge of the undulating membrane. This idea is set forth in the following words: "*On the so-called hind-body is found the — by* Stein *first very correctly described — saucer-shaped rim, on whose base is fastened the ring of the rigid baton-crown, from which the hooks arise. On the foundation of, and exterior to, the saucer-shaped membrane is implanted the chief locomotive organ of the animal, the posterior cilia-crown.* Siebold *has explained this as an undulating membrane, whilst* Stein *has evidently recognized the separate cilia of the same, and only speaks of a cilia-crown. The truth seems to me to lie intermediate, for though I clearly observed the single cilia, especially in dying animals, yet I could never follow them to the margin of the saucer, unless a fissure was present. This organ consists, then, of a membranous undulating border, on whose free edge vibratile cilia are inserted. One may convince himself best of this on dying animals, where one sees the gentle pulsations of the border and the cilia.*" Although it is certain that Busch did not see the velum, as such, and in its proper relations, yet it is not equally clear that he did not have it in view, but confounded it with the row of vibratile cilia which underlie it.

Finally, as the latest investigator, Claparède (*Études sur les Infusoires et les Rhizopodes, Mémoires de l'Institut Genevois*, 1858–59, p. 130) sustains the view of Stein, demurs to the opinions of Siebold and Busch, and says nothing about the true *velum*.

and forming it into pellets at the bottom of the œsophagus and its passage into the general cavity of the body may be seen at any time, and without any particular preparation. On this account it is no difficult task to ascertain the position of the mouth, and the trend of the vestibule and œsophagus, as well as the posterior termination of the latter.

The *vestibule* (v) is as distinct from the œsophagus (o) as in most of the Vorticellidæ. Its aperture (m) is very broad, and diverges almost insensibly into the peristome (d). It passes into the body in a direction which is in strict continuation (fig. 13) with the spiral trend of the border (d) of the disc; that is to say, it winds posteriorly, dorsally, and toward the right side of the body. In an end view (fig. 13) of the animal, the vestibule narrows rapidly from its aperture to its bottom, whereas when seen in profile (fig. 8, v) the diminution of its diameter is more gradual. When the body is fully expanded its aperture (m) is always open, and is circular, or broadly oval (fig. 12, m) in outline. This aperture lies just behind and exterior to the first spiral turn (fig. 11, b^1 to d^5) of the vibratory margin of the cyathiform disc, and receives the termination (fig. 13, b^2) of that spiral within its depths. It might, therefore, with propriety, be designated as the internal prolongation of the disc.

The anus (figs. 12, 13, a). When the anus is open, which not unfrequently happens, it appears as a distinctly bounded, seemingly margined aperture, which lies very conspicuously on the right side of the vestibule, and near its mouth.

The *œsophagus* (o, o^1), in conjunction with the vestibule (v), is an elongate sigmoid (fig. 13), funnel-shaped cavity, which extends obliquely backwards and across the body, nearly to its axis. When not in the act of taking in food, the *œsophagus* terminates in a fusiform point, or pharynx, and may be recognized as a clear, colorless space in the midst of the light yellow tissue of the body. From the point where it joins the bottom of the vestibule it curves to the left, and thus forms the dorsal termination of the sigmoid. In a profile view (fig. 8, o, o^1) it lies nearly parallel with the proximate or ventral surface of the body. When the pellets of food are forming, its posterior fusiform termination (o^1) — the pharynx, so-called — gradually expands into a globular cavity, which eventually exceeds in diameter the breadth of the mouth; but as soon as the food passes into the general digestive cavity, it assumes its accustomed funnel-shaped outline. As has already been stated in the section on prehensile organs, it is lined by vibratile cilia, which, it may be added here, seem to cover its whole interior.

The digestive cavity. Beyond the œsophagus there is no special cavity for the preparation or assimilation of food; the latter passes from the posterior end of the former through a simple, expansible aperture, directly into the general digestive cavity. The final assimilation of the food is accomplished, as in all other Vorticellidans, in a space which embraces every part of the body except that which is immediately occupied by the contractile vesicle (cv) and the reproductive organ (n). This space, therefore, serves both the purpose of a stomach and intestine; nor does it appear to have any accessory glands or appendages of whatever kind, that may assist in the process of digestion.

The *walls of the body*, therefore, form the immediate parietes of the digestive cavity. There are, at least, two of these walls. The inner one (p^1) consists of a clear, amber-colored, homogeneous, formless tissue, in which all the organs are imbedded. The other, or *exterior wall* (p), embraces the inner one like a film, and has more of the character of a colorless excretion than a true tissue. It is thickest about midway between the two ends of the body, and gradually thins out to an inconspicuous stratum at the anterior and posterior borders. Its surface is beset with excessively minute, short cilia, which, although occasionally and with great difficulty seen to move, cannot be called vibratile cilia in a strict sense, but rather pointed roughenings which are agitated by the varied contractions and expansions of the tissue from which they arise. The thickness of this wall is more or less deeply corrugated, principally in a longitudinal direction (fig. 14, *r, r*), and to a certain extent independently of the irregular folds and furrows on the outer surface of the inner wall.[1]

§ 7. The Circulatory System.

It would seem a little remarkable, at first thought, that the Vorticellidæ, which hold the highest rank among Infusoria, should possess a circulatory system which, in all but one genus, seems as simple in character as that of the lowest forms of the class, and apparently much less complicated than in *Stentor* and *Paramecium*, and others of the læotropic division. If, however, we look upon the numerous contractile vesicles of *Amphileptus, Trachelius*, etc., as indications of a diffuse, lowly organized circulatory system, and upon the fewer branching vesicles of *Paramecium, Spirostomum, Stentor*, etc., as tendencies to a greater degree of concentration, then the unique contractile organ of Vorticellidans would represent the consummation of this process, and consequently the most elevated status of the system, as it exists in this class of animals.

The *contractile vesicle* (*cv*) of Trichodina is a simple cavity which lies near the ventral side (figs. 8, 11) of the animal, a little to the left of the axial plane (figs. 12, 13), and consequently on the same side of the œsophagus, and about half-way between the anterior and posterior truncate ends of the body.[2] It contracts once in fifteen seconds. The systole occupies between two and three seconds, and the diastole proceeds slowly and continuously during the remainder of the quarter of a minute, until the vesicle has attained its maximum size (figs. 8, 11, 13, 14), and then it immediately contracts again. In specimens which are confined, or in the least restrained in their movements, the systole and diastole succeed each other much less frequently. At the full diastole the vesicle is perfectly globular, and occupies at least one third of the diameter of the mid-region of a fully expanded animal. The systole reduces it to an almost invisible point; and from this it gradually expands, first into a jagged (fig. 10, *cv*) star-like cavity, then into an irregular spheroid (fig. 12), and finally assumes, at full diastole, a globular contour.

§ 8. The Reproductive System.

As these observations extend over but a few days, — mostly at the beginning of October of this year, — the different phases in the development of the *nucleus* were not investigated. At the period just mentioned, this organ (n, n^1) had the form of a thick, knotted, or moniliform band, which extended in a uniform curve, over three quarters of a circle, around the truncate base, and in a direction exactly transverse to the axis of the body. Its two ends (n^1) lay next the ventral side, and right and left of the plane which passes through the œsophagus; and its breadth ran parallel with the axis of the body. It had a decidedly

[1] See, for further details, the section (§ 3) on the *form* of the body.

[2] There is a singular error in Stein's figure (*Infusionsthiere*, 1854, taf. VI. fig. 56) of the animal as seen from the basal end. The view of the base is underlaid by a view of the anterior end of the body, but the latter is posited *as if seen from the front*. To correct it, the contractile vesicle should lie to the right of the œsophagus, and the sigmoid flexure of the vestibule and œsophagus should be reversed.

yellow color, and was finely granulated throughout. In profile, or rather in a foreshortened view of its length, it was quite conspicuous, but where it extended across the vision it was so excessively faint as to nearly escape the eye, even though the utmost care was taken to ascertain its presence and exact position.

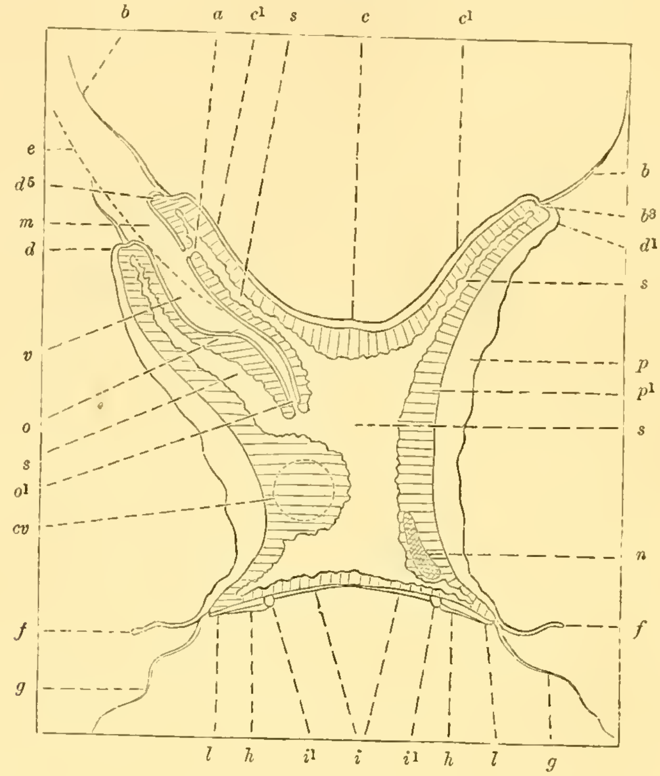
§ 9. Résumé.[1]

Reducing, now, the details which have been given in this memoir to the briefest expressions, we have the following summary in an aphoristic form. In its healthy, unrestrained condition, *Trichodina pediculus* is very dissimilar from the hitherto published representations of it. The illustrations of Ehrenberg, Dujardin, Stein, and Busch, represent the animal in an abnormal, more or less *reverted* attitude, — the result of studying the animal in a confined state, or when in an unhealthy condition. It has a deep, cyathiform, or dice-box shape, with an irregularly and longitudinally furrowed and plicated exterior. There is no *disc*, or it is represented by the depressed, cupuliform area which is bordered by the *vibratory crown.* The *peristome* is not a closed circle, as in Vorticellidæ proper, but follows the spiral course of the vibratory crown, and vanishes near the aperture of the vestibule. The *vibratory crown* consists of a single row of vibrating cilia, which winds along the margin of the spiral, dexiotropic peristome, just at the edge of the cupuliform disc, and descends thence to the left of the vestibular aperture, and entering it, plunges to the bottom of the vestibule, in an unbroken line. Neither Trichodina nor any of the Vorticellidæ possess a vestibular lash or bristle, and the latter is an optical illusion. The posterior truncate end of the body is margined by a well-defined, annular *velum,* immediately behind which, and arising from the same basis, is a complete circle of vibrating cilia. The so-called *adherent organ,* or apparatus of hooks and *radii,* consists, *firstly,* of a distinct, separable, annular border, whose opposite faces are dissimilarly striated by perfectly straight, transverse ridges; *secondly,* of a complicated circle of disseverable hooks, which are applied to the *posterior* face of the striated, annular border, along its proximal edge; and *thirdly,* of a series of Γ-shaped radii which lie, one by one, opposite the several hooks, and converge toward the axis of the basal plane of the body. The vestibule and œsophagus are as well marked, each in its own way, as in any of the Vorticellidæ. The vestibule opens near, and posterior to, the cilia-crowned margin of the sunken, cupuliform disc. The anus opens into the vestibule a short distance from its mouth, and on the right side. The contractile vesicle is a simple cavity, which performs its systole *once in fifteen seconds.* The reproductive organ is a knotted band whose antero-posterior thickness is much greater than at right angles to that; and it lies, in the form of a crescent, near the base, and transverse to the longitudinal axis of the body.

The extraordinary and almost incomprehensible position and form of the disc of this singular appendage of the Vorticellidan group seem to render it desirable that no pains should be spared to make the relations of its organs to each other as clear to the understanding as it is possible to do with the help of figures. The accompanying diagramic illustration of a longitudinal, sectional, or rather profile view of *Trichodina pediculus,* is particularly intended to exhibit the outline of the sunken, cup-shaped disc (c, c^1), and its close connection with the peristome (d^1, d^5); but in addition to this it is designed to show, in an outline sketch, the relations of the internal organs to the walls of the body. The contractile vesicle (*cv*), not being strictly in the plane of the section, is represented in dotted

[1] The principal points of this *résumé* are to be found in the *Proceedings of the Boston Society of Natural History,* Oct. 18th, 1865.

outline. The nucleus (*n*) is cut across its middle. The sigmoid figure of the vestibule (*v*) and œsophagus (*o*), being seen as it were edgewise, is foreshortened upon a flat surface. The lettering is the same as that used for the figures of the plate.



Explanation of Plate IV.

The corresponding parts in all of the figures of the plate and the wood-cut are lettered alike, as follows: — *a*, anus; *b*, vibratory crown; b^1, beginning of the vibratory crown; b^2, end of the vibratory crown within the vestibule; b^3, furrow of the vibratory crown; *c*, the bottom of the cupuliform disc; c^1, the side of the disc; c^2, the side of the disc rolled back; c^3, a front view of the disc; c^4, the "inclined plane" which lies upon the cornice-like oblique projection below the aperture of the vestibule; *cv*, the contractile vesicle; *d*, the peristome opposite the vestibular aperture; d^1, the dorsal region of the peristome; d^2, the inrolled edge of the peristome; d^3, the peristome at the edge of the inclined plane (c^4); d^4, the peristome where it becomes blended with the general surface of the body; d^5, the first turn, or ventral region of the peristome; *e*, the lumen of the edge of the row of vibrating cilia, hitherto supposed to be a distinct vestibular lash ("bristle"); *f*, the profile of the *velum*; f^1, the free edge of the *velum*; f^2, the basal edge or line of attachment of the *velum*; *g*, the basal cilia-crown; *h*, the hooks of the adherent organ; h^1, the circle formed by the bases of the hooks; h^2, the spur of *h*; h^3, the horizontal limb of the hook; *i*, the *radii*; i^1, the "nail-shaped piece;" i^2, the head of the same; i^3, the "*faint membrane*" or web of the Γ-shaped radii; i^4, the point of the nail-shaped piece; *k*, the crest of the hooks; *l*, the profile of the "striated membrane;" l^1, the distal edge of the last; l^2, the coarser striæ of the same, on its front face; l^3, the proximal edge of the same; l^4, l^5, a portion of the posterior face of the striated membrane, showing the finer striæ; *m*, the mouth of the vestibule; *n*, the nucleus, or reproductive organ; n^1, the left end of the nucleus; *o*, the œsophagus; o^1, the bottom of the same; *p*, the outer, and p^1, the inner walls of the body; *q*, digestive vacuole; *r*, longitudinal ridges on the surface of the body; *s*, the general digestive cavity; *v*, the vestibule.

All of the figures represent the whole or portions of *Trichodina pediculus* Ehr.

Fig. 1. An individual in the fullest degree of expansion. This is the most common form of the animal. 200 diam.

Fig. 2. Another, less frequent form of a fully expanded individual. 200 diam.

Fig. 3. An attitude occasionally, but briefly assumed by healthy specimens. The body is simply shortened, but without changing or reversing the relative position of the organs. 200 diam.

Figs. 4 and 5. Shapes assumed when swimming, different from those already described. 200 diam.

Fig. 6. An individual with the edge of the cup-shaped front (disc) rolled back so as to expose the bottom of the cup. 200 diam.

Fig. 7. A partially retracted individual, with one side of the cupuliform front rolled back. 200 diam.

Fig. 8. A profile view of the left side, showing the following parts, viz: the left flank (c^2) of the front partially reverted, and the right flank in the distance bearing the vibratory crown (b); the bottom (c) of the cupuliform disc in the distance, and its flank in profile (c^1); the contractile vesicle (cv), at full diastole, lying near the ventral side of the body; the peristome (d) opposite the mouth (m), *i. e.*, where the cilia — of the vibratory crown (b) — leave it and enter the vestibule (v), also the profile (d^1) of the same at the dorsal margin; the falsely called vestibular lash (*bristle*) (e) apparently attached near the dorso-anterior side of the vestibule; the *velum* in profile (f), and nearer the observer (at f^1) overhanging the base of the posterior row of cilia (g); the ring (h^1) of hooks of the adherent organ foreshortened, — *i. e.*, seen strictly edgewise; the left half (n^1) of the nucleus most conspicuous next the back, where its length is foreshortened; the œsophagus (o to o^1) partially filled by a nutritive pellet in the process of formation, and rapidly revolved by the action of the vibratile cilia; the filmy, colorless outer wall (p) projecting very conspicuously in profile, and in marked contrast with the bright amber-colored inner one (p^1); the general digestive cavity occupied by numerous "digestive vacuoles" (q), nutritive pellets, and smaller alimentary concretions; the wide aperture (m) of the vestibule (v), and the latter obliquely traversed by the posterior termination of the spiral, vibratory crown. 850 diam.

Fig. 9. A transversely sectional view of the mid-region of the body, to show its irregular contour, and the corrugations of the outer (p) and inner (p^1) walls. 850 diam.

Fig. 10. A dorsal view of an individual whose peristome (d^1, d^2) is inrolled, and with it the vibratory crown (b), which hangs down into the enclosed space about the partially raised, boss-like bottom (c) of the disc. The contractile vesicle (cv) is in partial diastole. The nucleus (n) lies next the back. The principal feature in this figure is the adherent apparatus (i, h, l, l^1), which is copied whilst it is in the act of embracing a highly convex surface, and has therefore an inverted saucer-shaped contour. The radii (i) are in the extreme distance; the hooks (h) project in the opposite direction; the striated membrane shows its breadth in the profile (l), and exhibits its milled edge (l^1) and the coarser striæ where it projects toward the observer. The *velum* (f) is at its fullest expansion, and allows its thickened margin (f^1) to be seen very distinctly, where it overlies the gaps between the groups of vibrating cilia (g). The cilia of the basal vibratory crown are represented as they appear sometimes when moving in groups or successive waves, and when they most resemble a torn, undulating membrane. 650 diam.

Fig. 11. A bird's-eye view of the left side and of the anterior end of the body, partially exposing the depressed face (c^3) of the cupuliform disc. The vibratory crown (b) is displayed throughout its length, from its beginning (b^1) on the right side over its spiral sweep by the ventral and dorsal sides, and thence to its downward coil into the mouth (m) of the vestibule. The peristome follows the same course as the vibratory crown, and appears as a distinct rim (d^3, d^5) just outside the base of the cilia, until, after descending along the edge (d^3) of the inclined plane (c^4), it vanishes on the left of the mouth (m). The false vestibular lash (e) or *lumen* of the vibrating tips of the cilia. The *velum* (f, f^1), shown very clearly in the profile (f), projecting like a tongue, and undulating independently of the vibratory cilia (g). The circle (h) of hooks and the striated membrane are drawn but just distinct enough to show their position. The mouth (m) of the vestibule appears as an oval aperture, lying between the first (d^5) and second (d^3) coils of the peristome. The œsophagus (o) is very much expanded at its bottom by a fully formed nutritive pellet, just at the moment when the latter is about to be passed into the digestive cavity. The nucleus (n, n^1) lies fully in view, with its left end (n^1) nearest the observer, and its right half in the distance, beyond the contractile vesicle (cv). 650 diam.

Fig. 12. A bird's-eye view of the ventral side and front of a slightly retracted individual, exposing the dorsal flank (c^3) of the cupuliform disc. The anus (a) appears as a distinct opening (when the fæces are making their exit) at the right side of the vestibule, whose interior is here partially exposed in the full-face view of the gaping mouth (m). The descent of the vibratory crown along the edge (d^3) of the inclined plane (c^4) is its most noteworthy feature in this view. Its beginning (b^1) on the right side of the front is also clearly brought out. The dorsal flank (c^3) of the cup-shaped disc presents an unobstructed view, but its bottom (c) is seen in profile through the side of the body. Its extension in the form of the inclined plane (c^4) has already been noticed. The contractile vesicle (cv) is represented in partial systole, a very marked feature when contrasted with its demi-diastole (fig. 10, cv). The peristome is particularly noticeable as a distinct border (d^3) along the edge of the inclined plane (c^4), and for its disappearance at the left side of the mouth (m). The pseudo-vestibular lash (e) or tips of the vibrating cilia raised above the position which they usually occupy, and in the attitude assumed during the expulsion

of the fæces. The *velum* (f, f^1) is only partially expanded. From the position of the animal the basal cilia (g) are exposed at full length. The hooks and radii of the adherent apparatus (h) are but dimly seen through the corrugated walls of the body. From its peculiar position in this view the vestibule is seen through the open mouth (m). The moniliform nucleus (n) is seen in the extreme distance, its right (n) and left ends are foreshortened, and appear as two very conspicuous, dark yellow, oval spots, easily seen even with a low magnifying power. 650 diam.

Fig. 13. An end view of the anterior face, looking directly into the cupuliform disc (c^3), and through its walls upon the various organs. The ventral region corresponds to the lower side of the figure. The anus (a) appears as a faint slit on the right border of the vestibule (v). The vibratory crown (b) commences abruptly on the right (b^1) side, and appears clearly defined as a spiral just within the peristome (d^1), and equally well marked where it forms a curve (b^2) at the bottom of the vestibule (v). It is quite evident, from this view, that the disc (c^3) is inseparable from the peristome (d^1), except by the slight, narrow furrow from which the cilia arise. The peristome is designated by a double border (d^1) (the outer and inner walls) along the spiral course of the vibratory row (b, b^1), but at the mouth (at d) of the vestibule (v) it loses that character, and gradually shades off (at d^4) into the surrounding surface. The lumen of the vibrating row of cilia — the vestibular lash (e) falsely so-called — appears distinct from this point of view. The contractile vesicle (cv) is in full diastole. Its distance from the ventral side of the body is rendered apparently unusual by the expanse of the disc (c^3). The circle (h, h^1) of hooks and the *radii* are in the extreme distance; the hooks partially overlaid by the knotted nucleus (n, n^1) and the œsophagus (o). The œsophagus (o) is in a scarcely expanded state, having but a few granules within it. The principal feature is its decidedly marked curve in the opposite direction from that of the vestibule (v). The "digestive vacuoles" (q, q) lie nearest the observer. 650 diam.

Fig. 14. A dorsal view of the body. The læotropic leaning of the cilia (b) of the vibratory crown is more decidedly marked than in the previous figures. The bottom (c) and flank (c^1) of the cup-shaped disc are seen in strict profile through the corrugations (r) and furrows of the outer (p) and inner (p^1) walls. The contractile vesicle (cv) is in the extreme distance, at its full diastole. The peristome (d^1) appears as a distinct ridge just exterior to the vibratory crown. The *velum* (f) is in a semi-expanded state. The cilia (g) of the basal crown are stretched to their full length. The circle (h) of hooks is scarcely recognizable as such in an edge view like this. The nucleus (n) lies next the observer. The outer wall (p), as in previous figures, bristles with numerous immobile, short cilia. The inner wall (p^1) is dotted everywhere by a minute scattered granulation. The longitudinal ridges (r) of the body bear a singular resemblance to muscles. 650 diam.

Fig. 15. A diagramic enlargement of the edge of the disc, principally to show how the cilia (b) arise from the furrow (b^3), and also the relation of the peristome (d^1) to the furrow. The outer (p) and inner (p^1) walls are represented in their relative proportions.

Fig. 16. A portion of the adherent apparatus, from a dead animal, to show the wrinkling of the striated membrane (l^1) and the overlapped, apparently forked, coarser striæ (l^2). The latter are seen through the thickness of the membrane, the finer striæ being omitted. The hooks (h) and radii (i) lie on the side next the eye. 950 diam.

Fig. 17. A basal view of the adherent apparatus, velum, and a part of the posterior row of cilia. The hooks (h) with their crests (k) lie nearest the observer, and partially covering the striated membrane (l^1 to l^5). The radii (i, i^1) with their webs (i^3) fill up the central area. The posterior face of the striated membrane with its finer striæ is shown from l^4 to l^5; and the anterior face of the same, as seen through its thickness, with its coarser striæ (l^2), between l^1 and l^4. The distal edge (l^1) is crenated and thickened. The proximal edge (l^3) runs along the bases of the hooks. The velum (f^1, f^1) is attached by its proximal edge (f^2) close to the distal margin (l^1, l^4, l^5) of the striated membrane, and almost the same with, but just anterior to, the line of attachment of the cilia (g, g) of the basal crown. Between l^5 and f^2 the striæ of the membrane are omitted. 950 diam.

Fig. 18. Two of the hooks and their corresponding radii, from the adherent apparatus of a dead specimen. The hook (h), its horizontal limb (h^3), the spur (h^2), and the crest (k) apparently form one solid piece. The *radius* (i) and the nail-shaped, transverse piece (i^1, i^2) are united at the angle by a triangular web (i^3). The mechanical contrivance for the sliding of these pieces upon and between each other is too obvious to need any comment. 2400 diam.

CAMBRIDGE, MASS., October, 1865.

Published February, 1866.

ERRATA.

Page 19, line 33, for ".98" read ".08."

Page 25, line 1, for "diameter" read "length."

Page 57, 2d line from top, for "cycle" read "series."

Page 57, 15th line from bottom, for "pharynx" read "thorax."

Pages 67 and 68, in six places, for "Mons." read "Prof."

Page 70, left hand diagram, transpose the "W" to the right hand end of the diameter line.

Page 75, 5th line from bottom, for "Della-Chiaje" read "Bojanus."

Page 78, after the table, read, "Note. In regard to the change in the name of the carpal flexors and extensors, see last paragraph on page 65."

Page 93, line 17 from bottom, for "*Athyris*" read "*Meristella*."

Page 99, line 18 from bottom, for "figure 18" read "figure 17."

Plate II. figure 2. *Cladopora verticillata.* The engraver has omitted the "a" which should stand at the upper left hand side at the semicircular notch.

Plate II. figure 15. *Conocardium ornatum.* The engraver has omitted the delicate radiating lines on the anterior side, and the delicate concentric lines of the rostrate side.

Plate III. figure 3. *Clidophorus McChesneyanus.* The muscular impression has been omitted in the engraving.

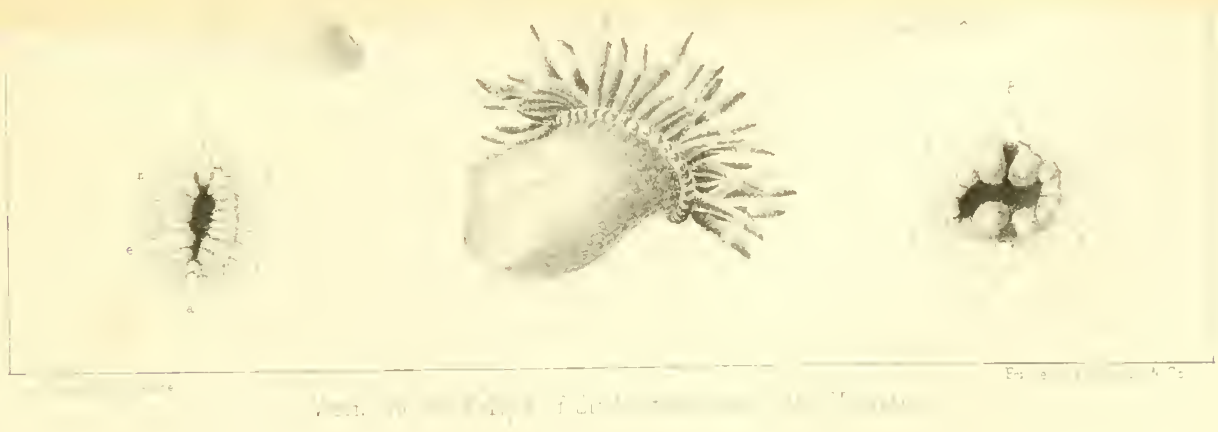
Plate III. figure 11. *Lichas decipiens.* The outline is palpably incorrect. Moreover, the lines separating the articulations of the lateral lobes do not exhibit the curvatures noticed in the description.

Plate III. figure 13. *Acidaspis Ida.* The engraver has omitted the furrow behind the ocular *filet* or thread on the right side.

Page 107. last sentence of first paragraph of Supplementary Note, the word "only" should be transposed, to follow the word "quoted."

Page 108, 2d line from bottom, for "relations" read "alations."

Page 108, last line, for "break" read "beak."



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Cambridge, Mass., October, 1865.

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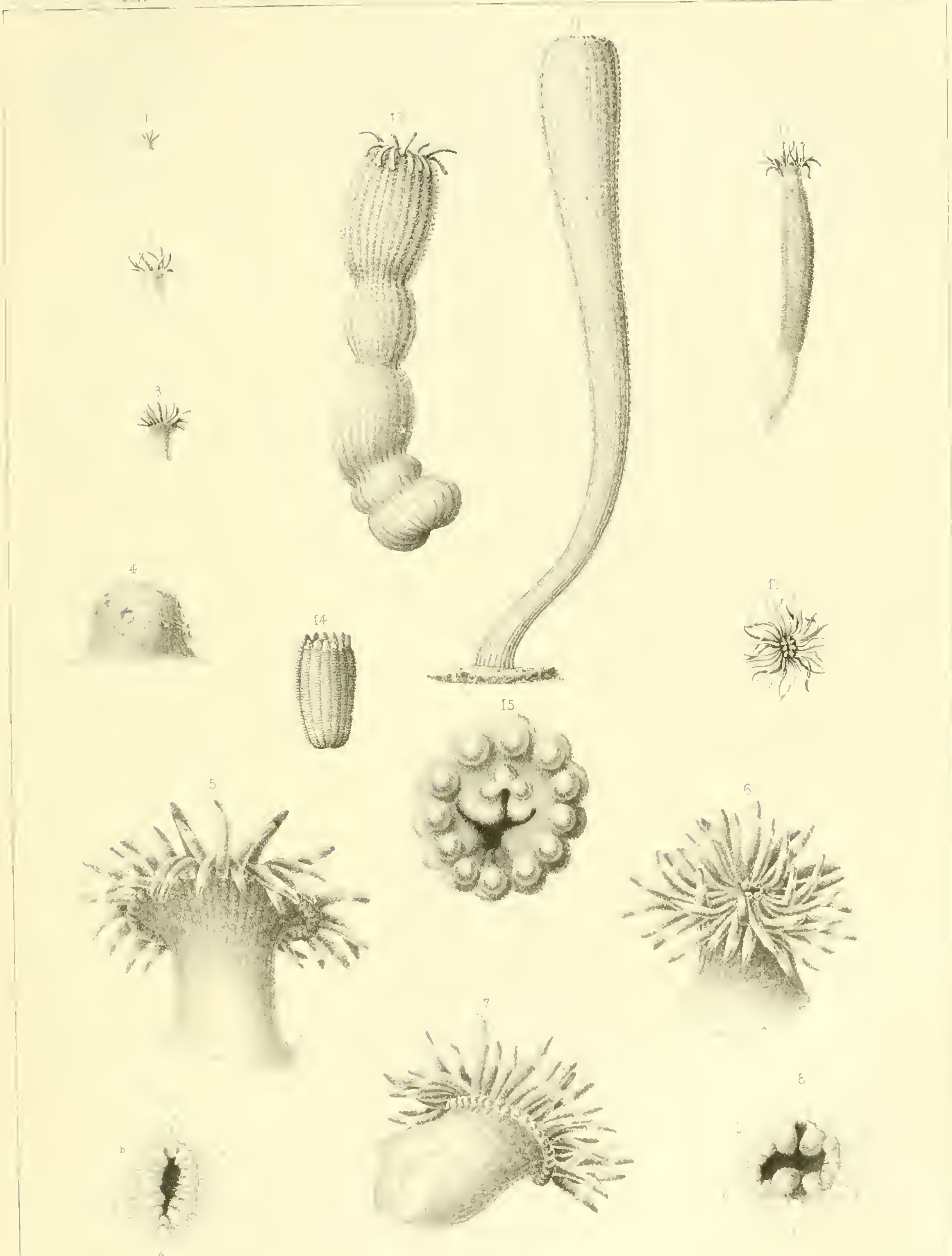
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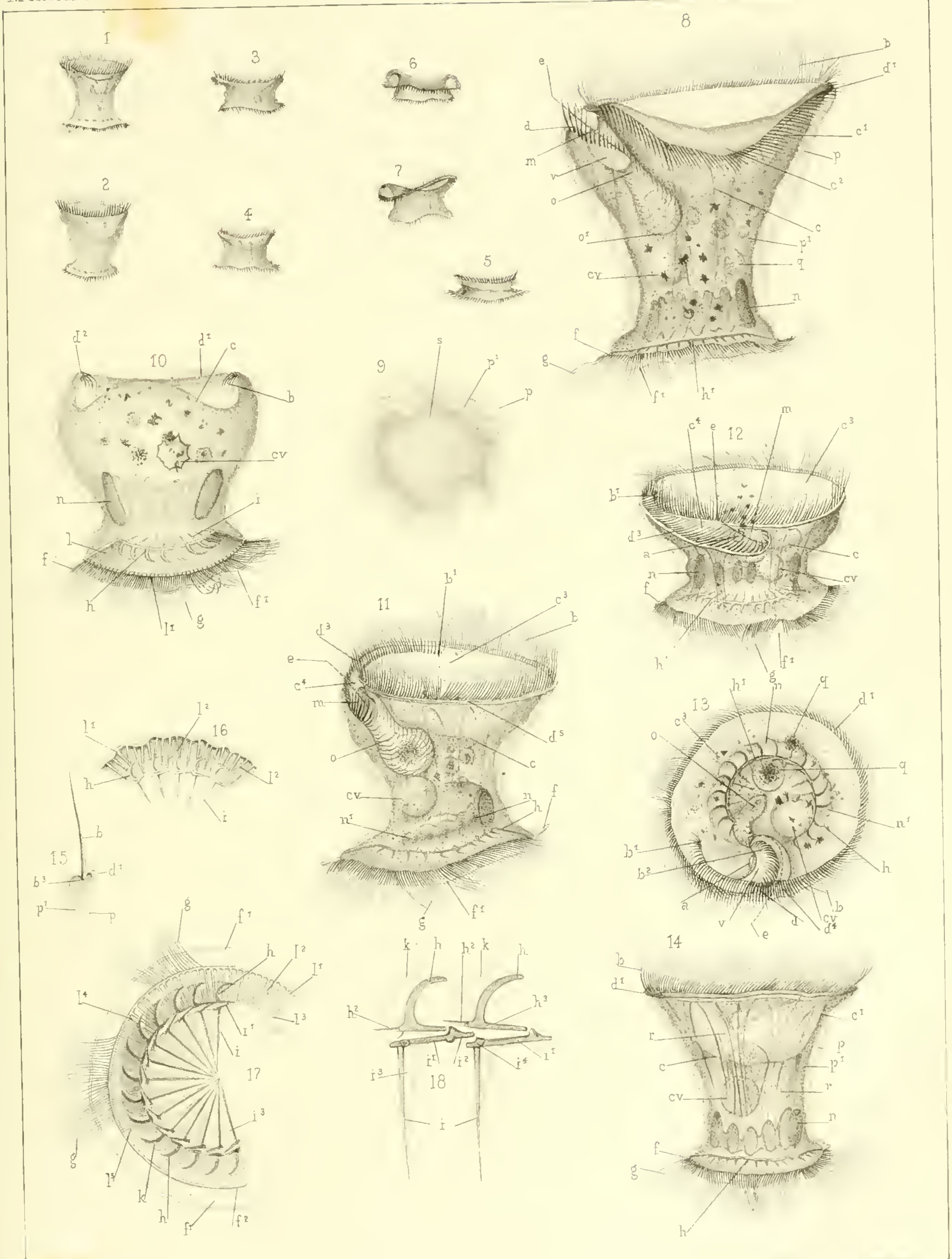
A. Winchell del. L. Trouvelot on stone J. H. Bufford & Co. print.

Winchell & Marcy on the Fossils of the Niagara Limestone at Chicago, Ill.

A Winchell del. L Trouvelot on stone J H Bufford & Co print

Winchell & Marcy on the Fossils of the Niagara Limestone at Chicago Ill.



H. J. Clark ad nat del

Printed by J. T. B...

H. James-Clark on Trichodina

MEMOIRS

READ BEFORE THE BOSTON SOCIETY OF NATURAL HISTORY.

VOLUME I. PART II.

I. *The Osteology of the* Colymbus torquatus; *with Notes on its Myology.*

By Elliott Coues, A. M., M. D.

Read September 16th, 1863.

THE *Natatores Brachypteri*, or *Urinatores*, so restricted as to exclude the Penguins, (*Ptilopteri*,) form an exceedingly natural group, quite closely adhering to a peculiar type of structure, as regards their bony framework and the muscles which act upon it. Their essential characteristics are found in the possession of a structure which, while it secures quite vigorous powers of flight, yet attains to by far its most perfect development in the production of natatorial powers, (unequalled except by those of the Penguins,) at a great sacrifice of capabilities for terrestrial locomotion. Progression on land is generally slow, awkward, and constrained; and is seldom or never protracted to any considerable distance, the bird always remaining in close proximity to the water. On the other hand, progression on or through the water is accomplished with a degree of facility and energy which at once stamps a peculiar character upon the whole tribe.

These remarks apply with particular force to that family of birds of which the common Loon may be considered as typical. In the genus *Colymbus*, the peculiarities of structure above alluded to reach their maximum of development, for the production of unsurpassed natatorial powers, at the expense of capabilities for terrestrial locomotion, which latter are remarkably imperfect. Both the osseous and the muscular system, therefore, of *Colymbus torquatus*, are probably typical of the morphology of these systems throughout the *Urinatores*, and are thus specially interesting and instructive as exemplifying the natatorial type of structure in a very perfect manner. The descriptive anatomy of them is applicable in a greater or less degree to the other genera of the tribe. The *Podicipidæ* are of course the most intimately allied; some of the genera of the *Alcidæ* may be more aberrant.

Although peculiarities are found in the whole structure of the bird, yet they of course are most marked in the posterior extremities; and I have therefore, in my descriptions, entered specially into detail regarding these parts, passing over other portions in a more summary manner. In the following pages, so far as the bones are concerned, it has been attempted to present the descriptive anatomy of the entire skeleton; while in the account of the muscles, only the more important have been noticed, special attention having been paid to those of the posterior extremities. In a paper like the present, it seemed impossible to present a complete myology, while such a procedure would be of doubtful utility. The scope of the paper is perhaps expressed in its title. Whatever may be its deficiencies or inaccuracies, it is offered in the hope that it may contribute its mite to the sum total of our knowledge of the anatomy of the class.

Of the Skull.

In the adult skull, the various bones of the cranium are, with the exception of course of the pterygoid and the tympanic elements of the temporal, so completely anchylosed that even the traces of their original sutures are scarcely discernible. The same may be said of the majority of the facial bones, especially the nasal, intermaxillary, and superior maxillary. The fronto-maxillary "articulation," however, and the palato-pterygoid and tympano-malar, remain freely movable. I will first notice the individual bones of the head, as well those which are anchylosed as those which remain permanently separated, and afterwards examine the skull, as a whole, upon its several aspects.

The *occipital* forms the posterior, and a small part of the inferior, aspect of the skull. Its basilar process is nearly smooth and flat, somewhat of a diamond shape, bounded anteriorly by the occipito-sphenoidal anchylosis, more laterally by the petrous portion of the temporal, posteriorly by the atloid condyle and foramen magnum. Just anterior to the condyle there are two considerable depressions for ligamentous attachments; and just externally to these, two slight elevations. Laterally, the occipital spreads out and rises into two prominent processes, the apices of which are rough for the attachment of muscles. From these condyles and from the basilar process, the "spinous" element of the bone arches upwards toward the parietal, leaving inferiorly the large orifice, — the foramen magnum. On either side these "spinous" plates are much depressed and rough for the attachment of muscles, and are separated from the parietal bones by elevated curved crests. On the median line they rise up to form an arched longitudinal elevation. The foramen magnum is broadly oval in shape, its long axis being antero-posterior. Above, its margins are very thin, being formed by the thin "spinous" plates of the occipital; they become laterally considerably thicker. Inferiorly, the edge of the foramen is occupied by the single condyle forming the occipito-atloid articulation. Its face is exceedingly convex; its general outline a semilune, the cornua presenting upwards, the greatest convexity directly downwards. Around the foramen magnum are several other foramina, for the transmission of some of the cranial nerves.

Sphenoid. The basilar process of this bone projects directly forwards from the basilar process of the occipital, in the median line, having on either side the pterygoid and palate bones, from both of which it is entirely separated. In this species, in which the orbits are so defective as to their bony parietes, it forms nothing of the floor of the orbits, but, by a vertical lamella of bone which projects forward, it contributes to form the inferior portion of the very deficient septum which exists between the orbits. From the posterior part of the base of the bone, the two "orbital" processes or plates extend upwards, forwards, and outwards, as thin lamellæ. They form the posterior walls of the orbits, separating them from the cranial cavity. Each is pierced near the median line, at its lower border, by the very large subcircular optic foramen; and external to these, by a smaller opening for the ophthalmic division of the fifth nerve. The second and third divisions of the fifth together perforate the bone much further back and more externally, in the depression just above the body of the tympanic bone. Just above the optic foramina are two others of considerable size, and of a regular quadrilateral shape. The alæ majores form that part of the skull intermediate between the zygomatic portion of the temporal and posterior orbital processes of the frontal.

Parietal. The complete anchylosis of the roof of the cranium leaves no traces of the original margins of these bones. The space which represents them is bounded posteriorly by the elevated crest marking the edge of the occipital, below and behind by the temporal, below more anteriorly by the alæ majores; on the roof of the skull they may be considered as projecting about as far forward as a line drawn between the two posterior orbital processes of the frontal. The space thus included is for a little distance on the anterior portion smooth, and covered only by the skin; but by far the greater portion of the bones form on either side rough, irregular, greatly depressed fossæ, generally styled the "temporal fossæ." These are entirely filled up, in the recent state, to the level of the rest of the skull by the temporal and masseter muscles. The two fossæ are separated from each other by a well-marked median longitudinal crest, from the anterior extremity of which two other equally elevated ridges proceed on either side to the posterior orbital processes, and form the anterior boundaries of the fossæ.

Temporal. This bone forms the infero-posterior angle of the skull, being situate between the parietal, occipital, and sphenoid. Superiorly, the "squamous" portion sends forward and downward the zygomatic process. The mastoid process seems to be indicated in that part of the bone which is continuous with the condyloid process of the occipital; it gives origin to the analogue of our *digastricus.* The petrous portion of the bone containing the osseous elements of the organ of hearing, lies internally on the inferior aspect of the skull, anchylosed with the side of the occipital basilar process. To the under surface of the zygomatic process is articulated the movable element of the temporal.

Os pedicellatum. This, the tympanic element of the temporal bone, articulates, by two separate, oval, very convex facets, placed side by side in a line oblique to the axis of the body, with two corresponding deeply concave depressions at the bottom of the fossa on the under surface of the zygomatic process. The depth of the depression in which the head of the pedicellate bone is received, together with a projecting border from the edge of the zygomatic process, tends to make the joint a very strong one.

From this articulating head the bone projects directly downwards and a little forwards for about three fourths of an inch. It first sends off its orbital process, — a stout compressed process of bone, projecting directly forwards and upwards into the orbit. This process has a considerable upward curve; its superior margin being concave, and running up quite to the head of the main bone; its inferior margin is convex, and merges into the main bone a little above the temporo-maxillary articulation. The top of this process is rough, for muscular attachments.

After giving off this orbital process, the bone becomes a little constricted into a "neck," upon which is supported the broad, irregularly shaped, and uneven head for articulation severally with the pterygoid, malar, and inferior maxillary.

The pterygoid facet is placed on the side of the head of the bone, just internal to, and below, the root of the orbital process. It is a single, obliquely elongated, smooth, very convex tubercle pointing inwards and forwards, on which the concave head of the pterygoid bone is placed. It presents something of the characters of the ball-and-socket joint, although rotation in all directions is not equally perfect.

Upon the opposite, *i. e.*, the outer aspect of the head of the pedicellatum, is placed the concavity for the reception of the head of the malar bone. It is on a lower level than the pterygoid facet, and presents more directly forwards. It is a nearly circular and exceedingly deep cavity. The small globular head of the malar is received into its concavity.

The somewhat extensive surface resulting from the expanded head of the bone is wholly occupied by the facet for the inferior maxillary. It is of an exceedingly irregular shape and uneven surface; in general terms, it may be said to be laterally much wider than long; to have a central depression bounded on each side and behind by elevations; and to be nearly divided into two lateral halves (corresponding to the lateral development of the head to produce the pterygoid and malar articulations), by a notch which cuts deeply into the posterior edge of the articulating surface To the inequalities of this surface, depressions and elevations in the lower jaw are accurately coaptated.

It is by this movable element of the temporal bone that the superior mandible receives the slight motion which it is capable of. The movements of this bone are transmitted by the malar to the superior maxillary, and by the pterygoid to the palatine, and thus the upper jaw is elevated or depressed according as the pedicellate moves forwards or backwards. The extent of motion that the upper jaw is capable of, however, does not seem to be as great as is the case with many other families.

Pterygoid. These are two straight slender bones about three fourths of an inch long, running obliquely inwards and forwards from the pterygoid facet on the inner edge of the head of the pedicellatum, to the posterior extremity of the palatine, with both of which they are movably articulated. Their shafts are slender, triangular on a transverse section, marked on their superior faces with a longitudinal groove. Both extremities expand into articulating facets. That of the posterior end is the largest; and besides the oval concave facet already noticed, by which it articulates with the pedicellatum, there is externally a small irregular projection which abuts against the inner side of the root of the orbital process of the tympanic bone. This seems to considerably restrict the extensive motion which ordinarily results from a ball-and-socket joint, and to give it rather the character of a free ginglymus.

The pterygo-palatine joint is a peculiar one. Two "claws," so to speak, project respectively from the upper and under surface of the bone, and grasp between them a small projecting point of the extremity of the palatine. The resulting articulation is most admirably adapted to its functions; chiefly that of *pushing* the palatine bones directly forward, but allowing also some inconsiderable lateral motion.

Frontal. This bone forms the whole of the roof of the orbits, but only a comparatively small part of the parietes of the cranial cavity proper. Its anterior border is quite straight, forming the directly transverse fronto-maxillary "articulation." The lateral margins are at first slightly bulging and convex, forming the anterior orbital processes; are then ascending and deeply concave, forming the superior margin of the orbits; and finally the bone stretches far downwards and backwards, to form the pointed prominent overhanging posterior orbital processes. Its posterior border is on the roof of the cranium anchylosed with the parietal, so as to leave no trace of the original suture; and in the back part of the orbits is equally fused with the orbital processes and alæ majores of the sphenoid.

Its superior surface is at first thick and rapidly ascending, forming the prominence of the forehead; in the rest of its extent it is flat, and gradually rises as it runs backward. It is marked in its whole length with a deep semilunar depression on each side, the concavity of which is parallel with and corresponds to the concavity of the superior margin of the orbit; the convexities of the two meet on the median line, where they are separated by a longitudinal ridge. The bottoms of these semilunar grooves are pierced with numerous minute foramina. At the anterior extremity of each is a large oval foramen, which transmits to the mucous membrane of the nasal passages the duct of the "nasal" glands which lie in these depressions; the secretion of which moistens and lubricates the pituitary membrane. Posteriorly, on the superior surface of the frontal, there is formed by the divergence of these two nasal fossæ, and by the crests which form the anterior boundary of the parietal fossæ, a smooth, diamond-shaped, elevated tablet of bone, — almost the only part of the surface of the skull over which the skin is directly superimposed.

The chief noticeable feature on the under surface of the bone is the continuation forward of the osseous canal through which the olfactory nerves escape from the cranium, as deep well-marked canal, spreading out anteriorly into a still deeper and larger oval fossa. This fossa occupies part of the frontal bone, but still more of the ethmoid; external to the fossa is the foramen opening into the beds for the nasal glands, with a groove running from the anterior edge of the foramen into the nasal passages, just along the inside of the root of the lachrymal bone.

Ethmoid. This is little more than a thin vertical lamina, placed in the median line, its superior margin anchylosed with the inferior surface of the frontal; its inferior margin similarly united with the long, projecting, basilar process of the sphenoid; its sides forming anteriorly what there is of an imperfect inter-orbital septum. Its posterior edge is thin and sharp, and forms the anterior margin of the large circular opening between the orbits. Its anterior margin spreads out superiorly so as to become of considerable width where it is fused with the frontal; below it is deeply concave, running forward some distance, with a pointed extremity. The superior part of the lateral surface of the ethmoid is hollowed into a shallow fossa for the olfactory nerve, as already mentioned. There is nothing to correspond with our cribriform lamella, nor with the spongy convolutions of the lamellæ of bone which so preëminently characterize this bone in mammalia. It still, however, performs the ordinary functions of separating the orbits from each other, and the nasal from the ophthalmic cavities, and of supporting the ramifications of the olfactory nerves.

Bones of the Face.

The facial bones, like the majority of the cranial, are in adult life anchylosed more or less completely with each other; the complex osseous structure thus formed having, as a unit, slight motion with the cranial bones, by means of the fronto-maxillary, pterygo-palatine, and tympano-malar articulations. Owing, however, to their peculiar form, the precise line of anchylosis can in most cases be more readily detected than in the bones forming the cranium. All the bones of the human face are repeated, with, it is true, exceedingly diverse shapes, but yet so markedly as to give rise to no difficulty in homologizing them; but the *intermaxillary* bone, although fused with the supramaxillary as in man, in birds forms the most prominent and important element of all, — preponderating vastly over the superior maxillary proper.

Lachrymal. From its position and connections this bone would seem rather to appertain to the cranial than the facial group. It is a thick, stout process of bone, five eighths of an inch long, projecting downwards and backwards from the under surface of the anterior corner of the frontal. It forms the continuation of the anterior boundary of the orbit. It projects downwards till it almost touches the malar bone, but is, however, quite unconnected with this or any other bone of the face, and does not have the least motion with them, being firmly anchylosed to the frontal. Besides forming the anterior continuation of the orbit, it forms a very partial and defective outer wall to the posterior part of the nasal passages. This bone, indeed, and the descending ramus of the nasal, are the only osseous lateral boundaries of the nasal passages throughout their whole extent.

Nasal. Firmly anchylosed basally with the root of the nasal process of the intermaxillary; movably articulated with the anterior border of the frontal. While its borders cannot be accurately defined, in consequence of its complete fusion with the intermaxillary, it sends downwards and forwards, at an acute angle, a conspicuous, stout, laterally compressed process which anchyloses with the superior maxillary, — appearing to be a direct continuation downwards of the intermaxillary. This process forms the posterior wall of the osseous boundary of the aperture of the external nares; forms with the lachrymal the lateral osseous boundary of the nasal passages; and connects the base of the nasal process of the intermaxillary with the superior maxillary bone.

Intermaxillary. This is by far the most important, as it is the largest and most conspicuous bone of the face; its various modifications in different families and orders of birds affording much the same data for zoölogical classification as do the teeth of the mammalia. In this species it measures three and a quarter inches in total length. Its outline along the culmen is slightly convex, especially terminally; both the mandibular and lateral outlines are a little concave. Distally, the bone consists of one piece, which is acutely pointed, arched superiorly, inferiorly with a deep longitudinal excavation, the beginning of the palate. About one and a half inches from the top it divides into three processes: a superior, mesial, "nasal" process, much the largest, running backwards as an elevated ridge supporting the culmen of the bill, anchylosed basally with the nasal bones and movably articulated with the frontal; and two lateral, basal, "mandibular" processes running along and forming the continuation of the tomia of the upper mandible, and finally merging by anchylosis into the superior maxillary, a little anterior to the zygomatic anchylosis.

The recess formed laterally by the divergence of the nasal and mandibular processes forms, with the nasal process of the nasal bone posteriorly, the large osseous boundary of the aperture of the external nares. It is an inch and a quarter in length, by a third of an inch high, sub-oval in shape, being narrow and compressed anteriorly.

The divergence of the mandibular processes leaves on the palate a narrow longitudinal opening, one fourth of an inch broad, covered with the lining membrane of the palate, except at the posterior part where begins the opening of the posterior nares. The fissure then becomes cleft in two by the vertically projecting vomer.

Superior maxillary. This bone is of inconsiderable size. It is difficult to define its contour with precision, as anteriorly it merges insensibly into the mandibular process of the intermaxillary; internally it is anchylosed with the palatine; superiorly the nasal bone becomes fused with it; while posteriorly it seems prolonged indefinitely into the long malar. That part of it which chiefly maintains its separate identity consists of a horizontal plate projecting directly inwards from the back and inner side of the bone towards the median line of the skull. This plate stretches to within a tenth of an inch of its fellow, the two being separated by the vomer, which passes between them. This represents the palatal process. From its inner border all around there arises a thin, delicate, concavo-convex lamella of bone, projecting upwards, outwards, and backwards, its free rounded margin inflected downwards so as to partially occlude a quite deep fossa, — probably the analogue of our maxillary sinus, — antrum Highmorianum. While the bones forming this sinus are tolerably broad, so as to divide the long palatine fissure into an anterior and posterior part, they are so depressed vertically as scarcely to rise at all into the large nasal passages. But for the fact that it forms this quite conspicuous "antrum," the superior maxillary would seem to constitute little more than an osseous band of connection between the four bones already mentioned as anchylosing with it. The important part which it plays in mammalia generally in the formation of the upper mandible is here quite usurped by the intermaxillary.

Malar or "*zygomatic.*" Long and slender, measuring about two inches in length. They form the lateral boundary of the inferior aspect of the skull. Arising from a perfect anchylosis with the superior maxillary, they at first curve a little outwards; then more outwards, with an inclination downwards; finally curving rather abruptly inwards and slightly upwards to the outer edge of the head of the pedicellatum. They transmit the motion of the latter directly to the superior maxillary, as the pterygoid do to the palatine.

The malar bone, properly speaking, extends only three fourths of the distance to the pedicellatum, the remaining being made up by the true zygomatic element of the temporal. Traces of the fusion of the two are still clearly traceable in several oblique lines and sulci.

Palatine. The palate bones are long and slender, lying along each side of, and near to, the median line of the skull. The width of their separation from each other forms the palatal fissure. This amounts on an average to about a quarter of an inch; but at their posterior extremities the bones almost touch each other, being separated only by the width of the thin sphenoidal spine. They begin very near the anterior extremity of the superior maxillary bone, lying along its inner border, being more or less completely anchylosed with it, and extending to within half an inch of its posterior termination. Thus far they are simply plain, narrow, flattened spiculæ of bone; but shortly after leaving the maxillary bones, they dilate laterally into very thin lamellæ, their edges so much inflected downwards as to give a transversely concave outline to their inferior surfaces. This dilatation ends quite suddenly by a rounded free margin, which slopes inward and bends upward to form the little projections which are grasped by the ends of the pterygoid bones.

From the anterior portion of the superior aspect of these horizontal plates there rises quite gradually a thin vertical lamella, which curls upon itself upwards and inwards towards the median line, forming that part of the inner edge of the bones to which the vomer is articulated.

Vomer. The vomer, as usual, is situated directly in the median line, forming an incomplete septum between the right and left nasal passages. It is just one and a half inches in length. Its inferior border, for one inch anteriorly, presents an exceedingly thin edge. For the rest of its length it is bifurcate, — the right and left portions divaricating from each other at a very acute angle, to articulate with the corresponding palatines. They are probably, however, more or less completely anchylosed with the latter, so that little or no motion is allowed. The superior surface of the bone is deeply grooved longitudinally for nearly its whole extent; the edge of the vertical lamella, the conjoined sphenoid and ethmoid, being received into this groove, and riding freely through it during the movements of the upper mandible. A little posterior to the termination of the ethmoidal spine, the bone sends out on each side a small but distinct lateral horizontal lamella. These run forward for half an inch, gradually narrowing till they no longer project; the groove along the superior surface of the bone also becomes obsolete; and the vomer continues a little way farther forwards, merely as a slender, very acute spine.

Inferior maxillary. Several of the original elements of which this bone is composed remain, as usual among the natatores, only incompletely anchylosed in adult life. The symphyseal elements present the most complete anchylosis, being firmly united for a little more than an inch. The angular and supra-angular pieces are also completely consolidated. The union between the two condyloid elements is less perfect, there being still traceable the evidences of their line of consolidation. The splenial element, however, remains quite distinct from all the others, except just at its lower end, where it is united to the angular. The piece produced by the union of the angular and supra-angular remains quite separate from the symphyseal element, being joined with it by the usual gomphosis. Along the inside of this joint the splenial element is applied obliquely; and posterior to it is the ordinary large unossified space. On the outside of the mandible proceeding from the gomphosal suture is the long oval foramen leading into the bone; and on the inside, nearly similarly situated but lower down, is a shorter and broader one.

In its general outline, this bone is quite straight, the rami not rising above the plane of the body of the bone, and the articular surface being on a level with its superior border. The tomal edge of the bone is almost perfectly straight, as far from the tip as the symphyseal element extends; then the superior border rises above the level of the articular facet, with an irregularly indented and somewhat curved outline; the principal elevation forming the "coronoid" process. This curved elevation terminates posteriorly in the depressed, broad, irregularly indented articular surface, — the inequalities of which are accurately coaptated to those of the articular facet on the os pedicellatum.

Posterior to the articulation, almost immediately continuous with it, is the well-defined triangular depression, presenting backwards and upwards, for the attachment of the principal depressor of the lower jaw, the so-called "digastricus." This space is bounded by well-defined raised borders; its inferior angle forms the posterior extremity of the bone.

The inferior edge of the bone is sinuate for its whole length. It is nearly straight from the tip as far as the consolidation of the symphyseal elements extends. Then, with a slight convexity, it curves upwards, and again downwards to the angle, forming an extensive concavity from the termination of the symphysis to the angle. The angle is pretty well marked though not acute, and it does not project much further below the level of the bone than the coronoid process does above it. From the angle, the inferior outline runs backwards with a moderate degree of upward obliquity, to just opposite the posterior border of the articulating surface, where it turns downwards with an abrupt concavity, to terminate at the apex of the triangular space above mentioned.

In its general shape and structure, this bone is very strong. The symphyseal elements are quite thick as well as deep, and their union very firm. More posteriorly, the bone is thinner, but this is compensated for by its greater depth. The articulating surfaces are very strong; and the total want of an obliquity in the line of union of the rami with the body of the bone confers a shape upon it which insures great stability and firmness.

Of the Cranium as a whole. Having considered the several individual pieces which go to make up the cranium, we will briefly notice the general characteristics of the skull as a quadrilateral pyramid, of which the tip of the bill is the apex, the occipital bone chiefly the base, and the superior, inferior, and two lateral aspects respectively the four sides.

The *base* presents rather a pentagonal outline. Superiorly, the two occipital crests converge at an angle on the median line, terminating below on each side with the mastoid processes. The lateral boundaries of the pentagon are formed by the pedicellate bones, the tempero-maxillary articulation, and the surface at the end of the inferior maxillary bone for the attachment of the digastricus. The fifth side of the pentagon is an imaginary line drawn from the posterior extremities of the rami of the lower jaw. Exactly in the centre of this pentagon is the semilunar condyle for the cranio-vertebral articulation; just above it is the large oval foramen magnum, between which and the occipital crests lies the flat, depressed "spinous" plate of the occipital, — the two sides of which rise into a longitudinal ridge at their union along the median line. On either side, the mastoid processes project conspicuously. Beneath these, and between them and the ossa pedicellata, are situate the internal organs of hearing. The space around the foramen magnum is pierced by several foramina for the transmission of nerves.

The *superior aspect* of the skull is bounded posteriorly by the occipital ridge, laterally by the parietal bones, the superior margins of the orbits, and the sides of the intermaxillary. The zygomatic processes of the temporals are the first lateral protuberances from behind forward; between these and the post-orbital processes, the crotaphyte depression is deep and well marked. The post-orbital processes are long and acute, the width between their apices representing the greatest lateral width of the skull. Anterior to these, the margins of the superior aspect of the skull are deeply concave, by the indentation formed by the upper margins of the orbits; the ante-orbital processes form a slight concavity on each side, just posterior to the fronto-maxillary suture. The tapering intermaxillary bone forms the remainder of the boundary of this aspect of the skull; its superior surface is occupied, as far forward as the post-orbital processes, by the large, deep "temporal" fossa, formed chiefly, however, by the parietal bones. Along the margins of the orbits lie the two long semilunar depressions for the nasal glands, separated by a median ridge from each other, their divarication posteriorly leaving between them and the temporal fossæ a central elevated, smooth, lozenge-shaped space. At their termination the glandular depressions are perforated with oblique oval foramina, which transmit their ducts through to the nasal cavities. The curved fronto-maxillary suture extends transversely across from side to side, its convexity presenting backward; the smooth nasal bones come next; and, taking its origin from between them, and stretching from the frontal bone to the tip of the bill, is the intermaxillary.

The *inferior aspect* is bounded laterally and apically by, and contained chiefly within, the two sides of the lower jaw, which divaricate from the symphysis, and extend the whole length of this aspect of the skull. Posteriorly, on the median line, lies the basilar portion of the occipital; just anterior to it, the spheno-occipital anchylosis, from which runs forward in the median line the elongated vertical spine of the sphenoid, to be received into the cleft of the vomer, and there anchylosed with the ethmoid. On either side of this spine are the pterygoid bones, running backward from the pterygo-palatal articulation, and diverging outwards to join the head of the pedicellate bones. More anteriorly, the flat, elongated palate bones extend the whole distance from the pterygoid to the bases of the superior maxillary, lying on either side of the median line, the vomer being interposed between them, and articulated with them by its posterior bifurcated extremity. As far as the anterior extremity of the vomer, the spaces leading up into the orbits and nasal passages have been divided along the median line into a right and left; but beyond this the palatal fissure is not cleft, but a single broad opening leads into the nares. The anterior single, and posterior double fissures are, however, continuous with each other, as the superior maxillary does not extend far enough inwards to meet the vomer.

The *lateral aspects* are each of a subtriangular shape, bounded by the margins of the three surfaces just described, with the planes of which they are united nearly at right angles. Their union with the posterior aspect is, however, at less than a right angle, in consequence of the lateral tapering of the skull from base to tip. Posteriorly the mastoid and zygomatic processes form conspicuous projections, below and internal to which are the internal organs of hearing. Anterior to this, extending between the under surface of the zygoma and the inferior maxillary articulation, is the pedicellatum, sending upward and forward into the orbit its orbital process. Just above the root of this process is the large circular foramen leading into the cranium, which transmits the second and third divisions of the fifth nerve; and the pterygoid bones are seen starting from just internal to the root of the orbital process, and running inward to the palatal.

The orbits occupy by far the largest portion of this lateral aspect of the skull. As usual among the *Natatores* they are exceedingly defective, not only as to bony margins, but as to septa between the two, and between them and the nasal and pharyngeal passages. The roof is formed centrally by the slight expansion of the frontal bone; the strongly developed post-orbital processes make a more complete arch posteriorly; while anteriorly, the slightly developed ante-orbital processes are eked out by the large strong lachrymal bones, which project downwards and backwards from the frontal quite to the malar, and complete the margin anteriorly. A very imperfect floor for the orbits is afforded by the slender elongated malar, the superior border of the inferior maxillary just within the malar, and by the horizontal expansions of the palatal. But the orbit is most defective posteriorly, where a bony parietis is quite wanting, and its place supplied by the temporal, masseter, and pterygoid muscles. The septum between the two orbits is formed by the vertical lamina of the sphenoid and ethmoid, but is very defective, a large circular aperture, more than half an inch in diameter, being closed only by dense membrane. Just at the posterior edge of this septum are seen the very large foramina for the optic nerves. There is really only one foramen leading into the cranium; but this is divided into two by the posterior edge of the vertical sphenoidal lamina, so that the nerves enter the two orbits by separate orifices. Other foramina, for the transmission of nerves and vessels, are found immediately about the optic. On the roof of the orbit is seen the longitudinal groove, emerging from the bony canal which transmits the olfactory nerve; and anterior and external to it, the large oval aperture which gives passage to the duct of the nasal gland. There is no bony septum between the orbits and the nasal passages.

Just anterior to the orbits, and separated from them by the lachrymal bone, is a triangular space. It opens into the orbits and the nasal passage, and communicates directly with its fellow, and projecting up in it is seen the horizontal incurved lamella of the superior maxillary. It is bounded below by the fused malar and superior maxillary bones, posteriorly by the lachrymal, anteriorly by the descending process of the nasal. This separates it from a large suboval aperture between the mesial and lateral rami of the intermaxillary, which forms the osseous margin of the external nostrils. It is one and a fourth inches long, by one fourth broad. Its axis is parallel with the nasal process of the intermaxillary, and therefore somewhat oblique to the longitudinal axis of the whole skull.

This aperture communicates directly with its fellow, and also with the palatal fissure, as as well as with the nasal passages generally.

Of the Vertebral Column.

Cervical vertebræ. The cervical portion of the spinal column consists of thirteen vertebræ. These, as usual among *Aves*, are very freely movable upon each other, not only antero-posteriorly in the direction of the axis of the body, but the lateral movement is also exceedingly free. There does not appear, however, to be anything very peculiar in their articulations with each other. The vertically concave and horizontally convex facet upon the posterior extremity of one vertebra is received into the vertically convex and horizontally concave anterior extremity of the next succeeding; and the smooth flat facets upon the oblique processes glide in the ordinary way upon each other. The planes of these articulations are so arranged as to produce, taken together, the ordinary "sigmoid" flexure of the neck of the bird. The feature of the extensive lateral motion of the neck appears to be more strongly marked than is ordinarily the case among the *Urinatores*, except perhaps the *Podicipidæ*; the long-necked genera of which, such as *Æchmophorus*, etc., probably surpass it in this respect. This lateral motion is most extensive between the lower cervical vertebræ.

Although these vertebræ possess characters which most readily separate them from those of any other portion of the column, they yet differ greatly from each other, in different portions of the neck. Throwing out of consideration the atlas and axis, which of course are quite unlike the others, we still find that scarcely any two vertebræ possess exactly the same shape, size, and special characters. Beginning with the third vertebra, and proceeding backwards, we find that the length of the bodies increases successively to about the eighth or ninth, when it again decreases rapidly, so that the last one is not so long as the third. The body of the third is thin, being exceedingly compressed vertically; and coincidently with the lengthening of each one successively to the eighth or ninth, they grow wider, and comparatively not so deep vertically; those that follow, however, do not again grow more compressed as they shorten; but on the contrary become broader and broader, so that the last one is as wide as deep, and very stout and strong. With this widening, there is also, towards the posterior extremity of this portion of the spine, a very high development of the transverse processes of the anterior extremities of each vertebra. This is so considerable, that the width across these transverse processes much exceeds the length of the whole vertebra. These processes are also exceedingly stout, with several roughened eminences for muscular attachments; and the foramen for the vertebral artery, which their two roots form, is as large as the spinal canal itself. Now as we proceed up the neck to the head, these transverse processes project less and less from the bodies of the vertebræ, and become less robust and angular, at the same time that they are antero-posteriorly elongated; and possess regular lamelloid walls. so as to form rather canals than simple foramina for the artery.

The "styliform processes" or "rudimentary ribs" appear to arise from the posterior aspects of the summits of each of the transverse processes, beginning with the third vertebra. They are directed backwards, exactly parallel with the axis of the column, and, according to their length, form a more or less complete osseous covering and protection to the vertebral artery during its passage between any two contiguous foramina. These styliform processes on the third vertebra reach quite to the transverse processes of the next succeeding, and, by keeping pace with the lengthening of the vertebræ themselves, are longest absolutely on the eighth and ninth vertebræ. They now, however, rapidly shorten, and lose their very peculiar features, until on the last cervical vertebra they are merely little pointed projections from the posterior aspect of the transverse processes. This fact of their rapid absorption towards the thorax renders the determination of the first true dorsal rib perfectly easy. These styliform processes are firmly anchylosed with the transverse processes and bodies of the vertebra to which they appertain, but have no connection, other than ligamentous, with the next succeeding one.

The superior spinous processes are well developed on the anterior vertebræ, as prominent crests or keels, running the whole length of the surfaces of the bodies; so much laterally compressed as to be thin laminæ of bone rather than "spinous processes." Their shape on the third and fourth vertebræ is not unlike that of the keel of the sternum. They gradually decrease in size as they proceed backwards; until, on the ninth and tenth vertebræ, they amount to little more than slight compressed tubercles. These enlarge again on the eleventh and twelfth, and on the thirteenth have assumed the general features of those on the dorsal vertebræ. Between the dorsal surfaces of any two contiguous vertebræ there is the ordinary aperture, closed only ligamentously, leading into the spinal canal.

The inferior spinous processes have the same general characters as the superior, — *i. e.*, they are found well developed at both extremities of the neck, but disappear in the central portion. Thus the third vertebra has a very large, well-developed process, whose base occupies the whole length of the body of the vertebra. This is much smaller on the fourth, is scarcely appreciable on the fifth, and is totally wanting on the successive ones to the eleventh. On this one, however, a spinous process reappears abruptly, being larger than any of the anterior ones, and is especially noticeable for its great projection forwards and downwards, and its exceeding thinness. The twelfth and thirteenth processes are successively smaller than this, but partake of all its general characters of shape.

The *axis* is chiefly noticeable for the great development of its ventral and dorsal spines, the former of which extends far downwards as a thin compressed lamella of bone, larger than the ventral spine of any vertebra except the eleventh. Nearly all of the body of the vertebra seems to be really comprised in this spine; and the facet for the articulation of the body of the third vertebra is situate on its posterior edge just at its base. The roof of the spinal canal is quite flat, and from its median line rises the dorsal spinous process, not really so large as the ventral, but still quite stout and prominent, and terminating in a thickened tuberculous apex. The flat roof of the spinal canal spreads out posteriorly into the transverse processes, which bear their articulating facets directly upon their under surface. The oblique processes, for articulation with the atlas, have their facets presenting directly outwards; and these are received within the ring of the atlas. The large facet which articulates with the body of the atlas is regularly oval, and quite deeply concave; the odontoid process well developed, convex in every direction upon its articulating aspects, flat on the side which presents toward the spinal canal.

The ring of the *atlas* is large, suboval in shape, its long diameter transverse. Posteriorly, it sends down on either side its slight transverse process, which overlies the anterior extremity of the axis. The fossa for the reception of the single occipital condyle is semilunar in shape, and very deep. Its concave inner border is formed to a considerable extent by ligaments, which separate it from the depression in which lodges the odontoid process of the axis, and serve to increase the depth of both these depressions. The body of the bone is, on the ventral aspect, prolonged as a spine of inconsiderable size, — the commencement of the ventral series of processes.

Dorsal vertebræ. If we consider the dorsal vertebræ as corresponding in number with the ribs, we should assign ten to this portion of the spinal column. The last three ribs, however, correspond to vertebræ which are completely anchylosed to the sacrum as well as to the iliac bones, and at the same time they differ in several respects from the dorsal ribs proper. It seems more natural, therefore, to consider these ribs as really appertaining to the sacrum, leaving seven to be viewed as true dorsal ribs, — and consequently to consider the number of dorsal vertebræ to be the same.

The transverse processes of these vertebræ are as usual very broad, long, and thin; their posterior borders concave, their anterior convex, and their postero-external angles prolonged backwards into a short "styliform" process, more or less intimately connected with the next succeeding vertebra. The horizontal lamellæ of the transverse processes of the last four vertebræ are pierced by a quite large foramen.

The superior spinous processes of the vertebræ are so long that they nearly touch each other by their anterior and posterior borders; only a slight space being left between them. They are quite regularly rectangular in shape, having straight flat superior borders at right angles with the anterior and posterior borders. They are connected with each other by dense and strong ligaments, and probably become more or less completely anchylosed with age.

The bodies of the dorsal vertebræ present the usual feature of being exceedingly compressed, until they are almost vertical laminæ of bone. But the most interesting feature of this portion of the spinal column is found in the enormous development of the inferior or ventral spinous processes. As the bird must be enabled to dart its neck forward with great power and rapidity, in the capture of its prey, we find these processes, which are the points of origin of the powerful *longi colli*, developed to a corresponding degree. The first ventral process consists of two broad thin laminæ of bone projecting downwards and outwards on either side, divided by a median ridge. These laminæ are sessile on the body of the vertebra. The second, third, and fourth are more peculiar. A compressed pedicle of a length increasing from before backwards, shoots down from the ventral aspect of the body of the vertebra, and bears upon its summit two broad, thin, flat lamellæ of bone, which, divaricating from each other at a very obtuse angle, expand outwards and downwards. These alæ are largest upon the third dorsal vertebra. Upon the fourth they are smaller; and on the fifth, sixth, and seventh become almost atrophied, although the pedicle retains its length. The pedicle of the fifth vertebra is the longest. These ventral processes are well developed on the first sacral vertebra, are merely a minute projection on the second, and totally disappear on the third.

The movements of this portion of the spinal column are exceedingly restricted, and if any exist, they are in a lateral direction. The last cervical vertebra is very freely movable in all directions upon the first dorsal. The last dorsal and first sacral have also perfect articulating facets; but their spinous processes are so extensively anchylosed, that it is probable that but little motion exists between those portions of the spinal column.

Sacral vertebræ. I have been unable to determine the exact number of vertebræ which compose the sacrum. Including the first three costiferous ones, the number is apparently about fifteen. They are throughout completely consolidated with each other, not only by their bodies, but by their processes, especially the dorsal spinous ones. The sacrum thus formed is exceedingly long and remarkably narrow in shape; having a lateral anchylosis with the iliac bones for nearly its whole extent. It is largest and stoutest opposite the acetabula and just posterior to them; where not only the bodies of the vertebræ are enlarged, but the long bony ridge produced by the perfect union of the dorsal spinous processes becomes widened and thickened. This long bony spine has but a slight curvature; so that while just posterior to the acetabula it is scarcely above the level of the iliac bones, yet at both extremities it is elevated some distance above them, by the convexity which their upper border presents. On the ventral surface of the sacrum its first three vertebræ have their bodies laterally compressed, so that a median ridge is produced analogous to that of the dorsal vertebræ. The transverse processes are also tolerably distinct. Just posterior to the acetabula, however, the transverse processes are hardly traceable, and the body of the sacrum has a median longitudinal furrow, instead of a ridge; more posteriorly again, the median ridge reappears, and the transverse processes become evident, intimately joined with the united ilia and ischia, each one separated from the next by an oval foramen.

Coccygeal vertebræ. There are seven bones in the coccyx, all freely movable upon each other. The first two are included between the projecting tubera ischii, which their transverse processes almost touch. Leaving out of consideration the coccygeal vomer, the bones have all the processes of the vertebræ of the other portions of the column. The transverse are largest on the fourth and fifth, becoming smaller both anteriorly and posteriorly. The superior spinous processes are well developed, the more anterior ones terminating by tuberculated extremities, which gradually grow smaller, till the last one is a simple thin lamella of bone. The inferior or ventral processes are rather stout thick tubercles than spinous processes; they are largest posteriorly, and decrease rapidly in size from behind forward.

The "vomer" is of moderate size. Its proximal extremity is deeply concave, bearing in its centre the round articulating facet. The thickening of the bone which forms this facet is continued along the middle of the bone to the extremity, as a prominent longitudinal lateral ridge. The superior border is very thin and sharp, nearly straight in outline; the inferior border curves gently upwards, and is thickened. The distal extremity is simply a small convex nodule, with no projecting process.

Ribs. The ribs are ten in number. Of these nine articulate with the spine, and eight with the sternum. Seven only are dorsal ribs proper; the eighth and ninth being articulated with the sacral vertebræ posterior to the tip of the crista ilii, and the tenth being connected neither with the spine nor sternum.

The determination of the first rib is rendered very easy and certain, by reason of the styliform processes or "rudimentary cervical ribs" decreasing rapidly in length from the cranial to the caudal end of the cervical vertebræ; so that on the last two or three they are merely slight pointed tubercles. Then from the first dorsal vertebræ the first rib projects as a very slender delicate pointed spicula of bone about two inches long, not reaching much more than two thirds the way to the sternum, terminating by a free unattached extremity. This rib is also remarkable for the shortness of its neck, and the consequent close approximation of its articulations with the body and transverse process of the first dorsal vertebra. In fact there is only left between them a small oval foramen.

The six succeeding ribs are the true dorsal ones, and present the characters of the ribs proper. Their necks are long and slender, and increase in length from before backwards; they support a head which is but very slightly enlarged. The tubercles of the ribs are very large and stout. In fact, these broad, flattened, transverse processes seem almost to form the true termination of the ribs, from which the neck and head proper seem but offsets. The ribs are very flat antero-posteriorly, and scarcely seem to grow narrower as they approach the transverse processes of the vertebræ. But from their inner surfaces there commences, at some distance from the vertebræ, the projecting ridge which is to be continued beyond the transverse processes to form the neck and head.

As usual, the ribs consist of vertebral and sternal portions, movably articulated with each other. Both of these portions grow successively longer from before backwards; but the sternal portions much more rapidly than the vertebral. Thus while the sternal portion of the second rib is barely three fourths of an inch long, that of the seventh is fully three inches. The angle at the junction of these two portions, of course, varies with every stage of an inspiration and expiration; but at any given moment the angles become successively more acute from before backwards, — from the increasing length of the vertebral as well as the sternal portions.

The processes which extend backwards and mesially from the dorsal ribs are well developed, extending not only to the next rib behind, but over it to the succeeding intercostal space. They are not straight, but curved, with their concavities towards the spine. The first one, that on the second rib, is the shortest, stoutest, and straightest; the others become successively longer, slenderer, and more curved, to the penultimate one, but the last one is shorter and smaller than it. These processes are at first only ligamentously joined with the rib, so that they may be easily broken off from the latter; but with advancing age they probably become more or less completely anchylosed. Each process is also connected with the rib from which it arises by a broad, dense, aponeurotic membrane of a triangular shape, extending from its concave border to its own rib, and along the rib to within a short distance of the spine; and with the next succeeding rib by muscular tissue. While each is thus firmly and unyieldingly connected with its own rib, it is enabled to assist the intercostal muscles proper in drawing the succeeding rib towards itself, these slips collectively thus exerting no slight force in the respiratory movements of the thorax.

The two ribs next succeeding the true dorsal, that is, the eighth and ninth pairs, differ from the dorsal in their origin, which is from the sacral vertebræ; and in their great length and tenuity, especially noticeable in their sternal portions, which are very nearly as long as their vertebral. The angle between the two portions is also very acute; but the most important difference is, that with the last dorsal ribs the processes just spoken of abruptly terminate,— so completely that on the ribs under consideration there is not even a rudimentary trace of their existence.

The last rib differs from all the others in being unattached at either vertebral or sternal extremity. It consists merely of two extremely slender elastic bones, tapering to a fine point, somewhat larger and broader at their bases, where they are joined to each other. The sternal portion is longer than the vertebral. Close by the junction of the two, this sternal portion sends off from its posterior border a small, slight process, which curves directly outwards and forwards, lying parallel with the posterior border of the rib, which it joins again about an inch from its origin, — leaving a space filled up only by membrane. This may very possibly be regarded as the rudiment of an eleventh rib, of which the vertebral portion is wholly wanting. It is sometimes entirely obsolete.

The latter ribs project so far backwards, that the thoracic parietes are prolonged some distance behind the acetabula, and consequently the femur in its normal position lies directly over the last three or four ribs, and moves backwards and forwards upon them. The angle of the last rib reaches within less than two inches of the posterior extremity of the elongated obturator foramen.

Sternum. This bone is sub-rectangular in shape, longer than broad, the greatest length being to the average width as two to one. The length in a direct line from the manubrium to the tip of the xiphoid cartilage is 7.25 inches; width opposite the superior angles, 3.25; width at narrowest part (which is opposite the facet for the sixth rib), 3.00; at widest part (opposite the middle of the apophyses), 3.75. Length of keel along its curved edge, 8.40.

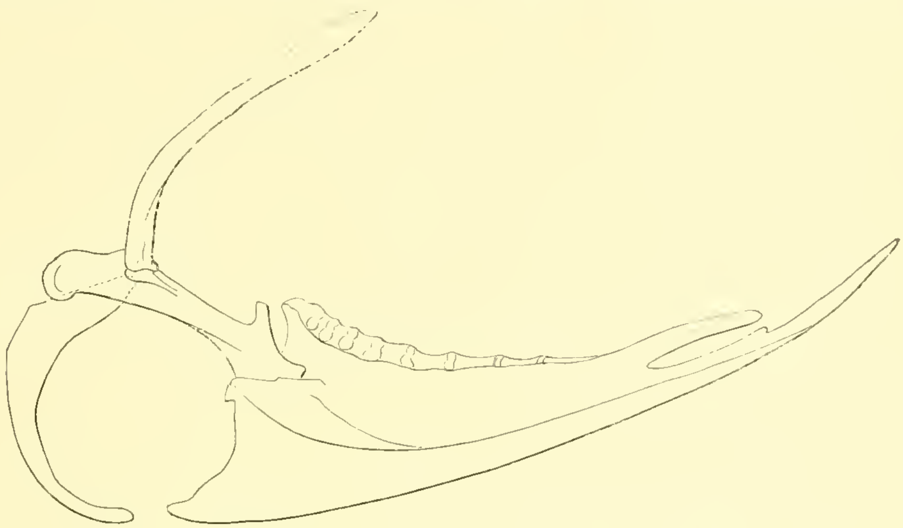
The anterior border is sinuate, projecting at the central line, running backwards as far as the groove for the coracoid bones extends, then turning forwards and outwards to the anterior angle of the bone. Directly on the median line lies the manubrium, in this genus extremely small, merely a slight triangular elevation of bone. The facets for the articulation of the coracoids are very deep sulci, meeting each other on the median line, and extending outwards for two thirds of the width of the bone. The edge of the sternum is thick and strong as far as these grooves extend; externally to them it is merely a thin plane bone supporting the costal facets, forming what are called the "costal processes."

The lateral edge of the sternum measures five inches in length. It is sinuate as regards both a vertical and horizontal plane. It is at first deeply concave, the edge introceding towards the central line; but it bulges out again opposite the base of the lateral apophyses, and then curves again somewhat towards the central line, producing a convex outline. This margin is quite thick anteriorly, but becomes posteriorly exceedingly thin and attenuated. It is marked with articular facets for the sternal ribs; these facets being closely aggregated together anteriorly, becoming much further from each other posteriorly till they cease opposite the base of the lateral apophysis.

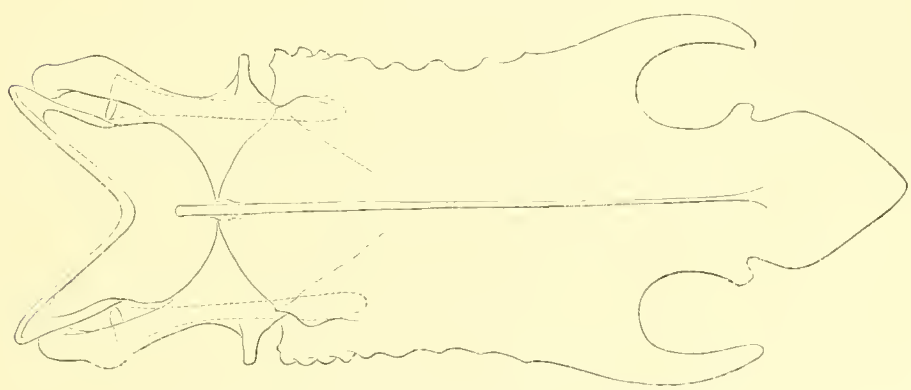
The posterior margin is a peculiar one; this arising from the great length and width of the xiphoid appendage, and the depth of the lateral excavations. Considering the posterior margin as beginning with the tips of the lateral apophyses, there is immediately a large elliptical excavation an inch and a quarter deep by nearly an inch broad. Across this is stretched the ordinary dense semi-transparent membrane. Just at the postero-internal border of this excavation there is another notch, but only a very slight one, scarcely a tenth of an inch in depth or width. From the edge of this second notch, the posterior border of the sternum on each side is regularly convex, meeting on the median line by a rounded but somewhat acute angle. This xiphoid appendage is very thin, and curls upwards and backwards from the plane of the sternum.

Posteriorly, the surface of the sternum is very broad and flat, or even slightly concave; anteriorly, it is narrower, and exceedingly concavo-convex, the sides rising upwards from the central portion which is thus caused to bulge downwards, with a very convex surface. The superior surface of the bone is quite smooth and free from inequalities; the inferior surface is marked with various ridges and roughened portions, indicative of the extent of origin of the several pectoral muscles. The most conspicuous of these is a ridge running obliquely backwards and inwards from the outer angle of the coracoid facet.

The keel begins just posterior to the small manubrial process, with a very thick, stout margin, which curves with a concave outline downwards and greatly forwards; so that the apex of the keel, which is quite acute, projects much in front of the anterior border of the sternum. The crest of the keel is regularly a little convex for its anterior half; in the rest of the length it is almost perfectly straight, to its subsidence into the level of the surface of the bone, which takes place just at the base of the xiphoid. The crest of the keel is broader than the vertical portion, and, with the latter, is rough for the attachment of the pectoral muscles. The vertical depth of the keel is, just at its anterior extremity, very considerable, being nearly one and a half inches; but very quickly, by the great



Sternum and scapular arch *in situ*, lateral view, one half natural size.
(Figure 1.)



Sternum and scapular arch *in situ*, from below, one half natural size.
(Figure 2.)

downward projection of the body of the bone, joined with the slight convexity of the crest of the keel itself, it becomes inconsiderable, and then more gradually decreases as it proceeds backwards.

Viewing, now, the sternum as a whole, we have to notice how great an extent of surface is secured with a trifling increase of weight. Posteriorly, this is attained by means of the great lateral projection of the apophyses, as well as by their length, and by the breadth and projection backwards of the thin, almost cartilaginous xiphoid. Anteriorly, where the sternum is not so wide, the deficiency is atoned for by the great depth of the keel, and its projection forward; at the same time the outline of the crest of the keel is such that when the inequalities of the bone are all filled up with muscular tissue the resulting surface becomes flat, and broad as well as long, affording the best possible outline for contact with the water.

Coracoids. These are very short, and exceedingly broad and stout. Each measures just three inches in extreme length. The "shaft" proper of the bone is reduced to a minimum of length, nearly the whole bone being taken up by the articular and other processes at the base and head.

The base of the bone is expanded into a broad, flat, trapezoidal surface, the sides of the trapezoid being all more or less concave. The postero-internal side is concave, smooth, and thin, fitting accurately into the articular groove in the sternum. The antero-internal border is simply a concave outline, running forward to become the inner edge of the shaft of the bone. The antero- and postero-external borders of the trapezoid are the most concave of all, being formed by a quite acute process of bone which runs directly outwards exactly under the costal process of the sternum.

On the inner aspect of the shaft of the bone, just internal to the coraco-scapular articulation, there is a lateral expansion of the bone, which curves upwards and forms the pulley over which glides the tendon of the pectoralis minor, in its passage to its insertion into the head of the humerus. This lateral expansion forms by its superior surface a good part of the coraco-scapular articulation. Its inner tip forms a little of the superior coraco-clavicular articulation.

On the shaft of the bone inferiorly there extends downward towards its head a stout thick ridge terminating in a convex, somewhat oval process, which bears upon its inner face a semilunar facet for the inferior or principal coraco-clavicular articulation. The external and superior aspect of the bone has a flat broad dilatation terminating in a convex facet lined with interarticular fibro-cartilage, forming the inferior half of the glenoid cavity. Upon the superior aspect of the shaft, just internal to the preceding facet, there is the somewhat semilunar facet for the coraco-scapular articulation.

Clavicles. These bones are altogether weaker, and meet at a more acute angle, than we should expect to find in a bird possessed of the powers of flight of the Loon. The angle formed by their divergence is scarcely more than 45°. At their broadest part, which is near their origins, they are over half an inch wide, but exceedingly thin. This width decreases rapidly towards the symphysis, where the bones are very weak and slender, and oval or elliptical on a transverse section. The symphysis is a simple fusion of the two clavicles, without any projecting lamella or process, and unconnected except ligamentously with the apex of the sternal keel. Each of these bones articulates in two places with the coracoids, as has been already pointed out. From these articulations the bones when *in situ* dip at first directly downwards, then with a very convex outline run backwards, at last curving upwards again to the symphysis with a considerable degree of convexity. From the peculiar articulation of these bones with the coracoids at two points it results that the curved surface which serves as a pulley for the play of the tendon of the pectoralis minor is converted into a complete bony canal.

Besides the proper articulation of these bones with the coracoids, they are throughout their whole extent bound to the latter by a dense layer of fascia, the supraclavicular, which is stretched vertically between the bones.

Scapula. The scapula, as in most birds, is simply a long, narrow, flattish bone, lying superimposed upon the dorsal aspect of the ribs, nearly parallel with the vertebræ, and situate somewhat more than an inch from them. It measures 3.60 inches in length, by about one fourth of an inch at its lower, and three fourths at its upper or broadest end. It is concavo-convex in two planes: *i. e.*, slightly so in the horizontal plane, its convex edge being presented towards the vertebræ; and much more decidedly so in a vertical plane, the convexity presenting upwards. In the greater portion of its length the transverse section of the bone is elliptical or oval; but towards the distal extremity it becomes depressed into a simple thin flat lamina. This lamina is nearly straight and very thin, and forms the termination of the scapula without curving in any direction. The proximal extremity of the bone is much thicker and stronger than the rest. It bends downwards with a very considerable, and inwards with a slighter, curve. The thick head of the bone, thus constituted, articulates with three bones, — the clavicle, coracoid, and humerus.

The claviculo-scapular articulation is a mere apposition of the extreme apex of the clavicle with a very small space just at the internal edge of the head of the scapula, where that edge projects inwards upon the expanded lateral process of the coracoid, which forms most of the second or superior coraco-clavicular articulation.

The coraco-scapular articulation is an exceedingly strong and firm apposition of the whole head of the scapula with the rough depression on the superior surface of the shaft of the bone, just internal and posterior to the glenoid cavity. The articulation seems to be essentially almost a synchondrosis. The rough inequalities of the head of one bone are perfectly coaptated to those of the other; interarticular fibro-cartilage is interposed; and the whole articulation is so firm and unyielding as to permit of but exceedingly limited motion, and that chiefly in one direction. That part which the scapula takes in the formation of the glenoid cavity constitutes the humero-scapular articulation. The glenoid cavity merits special notice.

When the glenoid facets of the coracoid and scapula are deprived of the dense layer of fibro-cartilage which chiefly forms the concavity in which the head of the humerus plays, they are found to be perfectly smooth and plane. Both are tolerably regularly oval in shape, the coracoid the larger, and quite oval, the scapular smaller, and more of an elongated and subtriangular shape. The coracoid facet is horizontal antero-posteriorly, with transversely an obliquity of about 45° upwards and outwards; the scapular is about perpendicular to it, with transversely 45° of obliquity forwards and outwards. Upon this osseous basis a very dense and thick layer of unyielding fibro-cartilage is superimposed, to form the slight concavity which exists for the reception of the head of the humerus. This cartilage is laid over the whole of both facets, but is much the thickest at their margins, where it rises with a well-defined edge, leaving a central depression which constitutes the true glenoid "cavity." This cavity is very broadly semilunar in shape, the cornua of the semilune having quite well-defined, raised borders, its convexity being but slightly, and its concavity scarcely at all, elevated. But the depression is so slight that the entire cavity is able to contain but a comparatively small portion of the articular head of the humerus. This disposition of the elements of the articulation, as well as the shape of the head of the humerus, is plainly indicative of the design of the joint, — the attainment of great freedom of motion in all directions by some sacrifice of strength. A comparison of the glenoid with the cotyloid cavities of this bird furnishes a striking illustration of the preponderance of *mobility* over *stability* which usually obtains in the anterior extremities of the higher vertebrates.

The disposition of the fibro-cartilage above noticed, by which the glenoid cavity is augmented in depth, is strictly homologous with the raised border of cartilage which surrounds the same cavity in man, and which subserves the same purpose. The same plan, according to Owen,[1] exists throughout the lower orders of birds, the *Rasores, Natatores,* and *Grallatores;* while in the more highly organized birds, the *Raptores* and *Insessores,* there is found a distinct bone, the "*os scapulare,*" or "*os humero-scapulare,*" which subserves the same purpose.

Humerus. This bone is moderately long for the size of the bird, but quite stout and strong, and especially notable for the extensive development of the crests and processes near its proximal extremity. It measures between seven and a quarter and seven and a half inches in extreme length. The shaft is centrally very nearly circular on a section; towards both extremities of the bone it soon becomes flattened in a plane about half-way between the vertical and horizontal,—at the distal extremity to form the two condyles; at the proximal, to expand into the well-marked superior and inferior crests. The superior crest is very high and long, extending from the articular head to beyond the middle of the bone before it is obliterated; but it is only conspicuously elevated for about one and a half inches of its length, for the greater part of which extent it affords attachment to the broad tendon of the great pectoral. Mesial to this crest, on the shaft of the bone, about an inch from the head, is the small tubercle for the attachment of the conjoined tendinous slips from the latissimus dorsi and the long extensor cubiti. The inferior crest curves as usual in the opposite direction from the superior. It is much shorter, broader, and thicker than the superior, and is placed obliquely to the shaft of the bone, that is to say, parallel with the inward inflexion of the proximal end of the shaft towards the glenoid cavity. Its under surface presents well marked the ordinary deep fossa; its superior surface near the articular head of the bone also another fossa, more shallow, however, than the inferior. The proximal extremities of both of these crests are marked with several tubercles and facets for the insertion of various muscles, the majority of all the muscles which act upon the humerus being inserted into one or the other of them.

Between the proximal extremities of these crests is situate the articular head of the bone. It is of an oval shape, exceedingly convex in its transverse, less so in its longitudinal axis. Its face is placed obliquely with reference to the shaft of the bone, from the fact of that part of the bone which supports it curving inwards to meet the glenoid cavity. Its long axis, which is placed directly between the extremities of the superior and inferior crests, is not quite vertical, but inclines obliquely outwards and upwards. The nature of its connection with, and movements in, the glenoid cavity, have already been adverted to.

The distal extremity of the bone presents well marked the great peculiarity which characterizes the elbow-joint of the class *Aves;* namely, the hemispherical tubercle for the ulnar articulation, and the elongated oblique tubercle, extending somewhat along the shaft of the bone, over which the radius moves. The necessity for the very peculiar shape of these articulating facets arises from the obliquity of their plane in relation to the plane of the circle which the ulna and radius describe in the unfolding of the wing. The articular facets do not project directly outwards, but obliquely downwards and outwards, so that, in the folded wing, the distal extremities of the ulna and radius are below the level of and external to the proximal extremity of the humerus. Now, in extension of the forearm, by the peculiar motion which the radius has over the elongated oblique tubercle with which

[1] In Todd's *Cyclopædia of Anatomy and Physiology,* Article *Aves.*

it articulates, its distal extremity describes a greater arc of a circle than does that of the ulna; so that, although the plane of the circle in which these bones move is oblique to the axis of the humerus, yet during extension this obliquity becomes gradually less and less, until at full extension it quite disappears, and the bones of the arm and forearm lie in the same plane.

It is exceedingly interesting to compare this articulation with the elbow-joint in the human species. In the latter, the connection between the ulna and humerus is most strictly ginglymoid, admitting of only backward and forward motion; while pronation and supination are perfect, by the very free rotation of the radius upon the outer tuberosity of the humerus, and around the distal extremity of the ulna; but the radius also has, in common with the ulna, the ordinary ginglymoid movements of flexion and extension. Thus the elbow-joint, taken as a whole, and considered with reference to the movement of the forearm upon the arm, is strictly a ginglymus, notwithstanding the element of the *diarthrosis rotatorius* of the head of the radius. In birds, although pronator and supinator muscles exist, yet they seem to serve rather to steady the radius than to move it, and the pronation and supination of the forearm is exceedingly limited, if indeed it exist at all. While, therefore, the axes of the two bones of the forearm scarcely change their relations to each other, the common plane of their two axes is continually changing its relation to the axis of the humerus, in flexion and extension of the forearm. This peculiar character of the movements of the forearm is arrived at by the complete obliteration of the element of *rotation* in the humero-radial articulation, and the conversion of the direct antero-posterior ginglymoid motion into an oblique ginglymus. As the ulna must of course accompany the radius in this obliquity of its flexion and extension, the deep sigmoid cavity is converted into a shallow circular depression, which receives the small hemispherical articulating facet of the humerus. By this means it can adapt its motions to any degree of obliquity which may be impressed upon it by the position of the radial articulating surface.

Another interesting feature in this joint is that it is not the head of the radius alone which articulates with the radial facet of the humerus. That part of the head of the ulna which lies immediately above and posterior to the radio-ulnar also plays over this outer oblique tuberosity of the humerus, forming with the rounded head of the radius an elongated depression, which accommodates itself to this elongated radial facet. In this feature of the articulation of the head of the principal bone of a limb with *both* the condyles of the bone above it, is seen an indication of what exists in the femoro-tibial articulation of the human species; and since it seems to denote a tendency of the element of stability to preponderate over that of mobility, it is what we might expect to find when we remember how fixed the radius is to the ulna, causing the motion of the forearm to be limited to flexion and extension.

The posterior aspect of the end of the bone presents two well-marked longitudinal grooves, completely separated from each other by a median ridge. These grooves give passage to the tendons of the two extensor muscles of the forearm, proceeding to be inserted respectively into the outer and inner sides of the olecranon. The olecranonoid depression is hardly recognizable as such; and the coronoid is but slightly marked.

Ulna. As usual, much larger throughout its whole extent than the radius, and quite as large at its distal as at its proximal extremity. It is a little less than six inches long. Its shaft is considerably curved in its whole length, subcircular on section, being flattened along its inner aspect. Its external border is marked by oblique ridges corresponding to the insertions of the secondary quills. The olecranon is a somewhat compressed process at the posterior aspect of the head of the bone, but does not extend above the margins of the articular cavity. This latter is placed upon the inner and anterior aspect of the head of the bone, and has been already described. Just external to, and below it, is the radio-ulnar articulation. It is merely a slight subtriangular depression, against which the head of the radius is apposed, and has leading from its superior margin the continuation of the facet on the head of the radius, for articulation with the external oblique tuberosity of the humerus. Both lateral surfaces of the head of the ulna are rough, for the attachment of muscles.

The distal extremity of the ulna is fully as large as the proximal, but of quite a different shape. It is greatly flattened horizontally, the anterior margin projecting forwards as a flat ridge, over the superior surface of which passes the radius. The articulation of the radius with the ulna is however merely by a small facet on the middle of this superior aspect of the head of the bone. The greater part of the remaining surface of the head of the bone forms a smooth, somewhat semilunar depression, by which it is articulated, partly with the posterior half of the head of the metacarpal bone, and partly with the small carpal bone, as is more particularly described further on.

Radius. The radius is exactly of the same length as the ulna, but much smaller than it throughout its whole extent. It is quite straight except just at its distal extremity, where it is somewhat decurved to overlap the extremity of the ulna. Towards its lower extremity it increases in size, though not to any great degree, and becomes horizontally flattened. Its rounded head, considerably larger than the shaft below it, bears upon its inferior border the small ulnar articulating facet, and upon its face the much larger and somewhat oval depression for articulation with the humerus. Its distal extremity is marked superiorly with a very deep groove, which continues for some distance up the shaft for the lodgment of the tendon of the extensor metacarpi radialis. Just internal to it is another groove, but much shorter and less conspicuous.

The radius articulates below with the ulna, as already described; but its principal articulation is with the large bone of the carpus. Nearly the whole of its extremity is occupied by an oval facet, long in its horizontal diameter and transversely very convex, which is received into the deep concavity on the radial aspect of the carpal bone. This radio-carpal articulation presents just the opposite feature from that of man, a convexity of the end of the radius being received into a concavity in the carpal bone, instead of the reverse.

Bones of the Carpus. Of the two carpal bones, that corresponding to the scaphoid, semilunar, and cuneiform, is the largest, and articulates chiefly with the radius. It is wedged in at the outer angle of the joint between the metacarpal bone and the radius, extending far enough towards the ulnar side of the joint to articulate with the ulna by a small facet. It is of a very irregular shape, marked with three facets, for articulation respectively with the radius, ulna, and metacarpus, and with two deep grooves for the lodgement of tendons.

The deep radial facet has been already noticed. Just on the opposite side from it, the face of the bone presents the smooth depression for the reception of the head of the metacarpus; this facet is divided into two parts by a vertical median ridge, corresponding to the vertical depression in the head of the metacarpus. The very small facet upon the interno-posterior aspect of the bone articulates with the radial edge of the large terminal facet of the ulna.

Upon the superior surface of the bone there runs longitudinally the continuation of the deep groove of the radius which lodges the extensor metacarpi radialis. At right angles with this and running transversely, there is a still deeper groove which conducts the tendon of the flexor metacarpi radialis.

The second, smaller bone of the carpus, which represents the second row of carpal bones, is placed just in the bend of the joint, on the ulnar side, wedged in between the ulna and metacarpus, with both of which it articulates. Its ulnar aspect presents a smooth, oval, somewhat depressed facet, which plays against the extremity of the large articulating surface of the ulna. Its metacarpal aspect presents a very deep horizontal notch or fissure, into which is received the inferior thin border of the metacarpal bone. In flexion and extension of the metacarpus, this small bone rides backwards and forwards along the edge of the metacarpal bone, being as it were astride of the latter. The non-articular aspects of the bone are rough for the attachment of tendons.

Metacarpus. In the single metacarpal bone, which, as in all birds, results from the fusion of the five of the human species, there may be clearly traced three distinct bones.

The first, which corresponds to the metacarpal of the thumb, is found superimposed upon the radial edge of the metacarpus, and intimately blended with it, appearing like an elevated crest. It is about one and a half inches long, and bears upon its distal extremity the pollex or thumb.

The second, or metacarpal of the little finger, lies directly upon the ulnar side of the bone, and is much more distinct than the preceding. It is from its origin for about half an inch, fused with the main bone, but then becomes entirely separated from the latter by a considerable hiatus, running forward to be again united to it about half an inch from its distal extremity. It supports upon its tip the "ulnar finger."

The remaining greater portion of the metacarpus results from the coalescence of the three middle bones of the human hand. This supports the three phalanges of the "radial finger," and articulates with the radius and ulna.

The metacarpus, thus constituted, is a strong bone, nearly four inches long by about five eighths of an inch broad at the broadest part, much compressed. Its proximal extremity is taken up wholly by a single large, smooth, articulating facet, which moves upon the ulna and both of the carpal bones, but has no connection with the radius, the large carpal bone being interposed between it and the head of the latter. This articulating surface is exceedingly convex from the radial to the ulnar side; but presents in the median line a deep sulcus running its whole length, causing the transverse outline of the head to be concave. The greater part of the head is joined by a strictly ginglymoid articulation to the central portion of the large facet on the ulna. At the radial side the articulation is with the large carpal bone; at the ulnar, the inferior border is prolonged backwards, and forms the prominent ridge over which rides the smaller carpal bone, as already described. On either side of the articulating surface the bone presents rough elevations and depressions for the insertion of tendons and ligaments. On its superior aspect the bone is also marked with several longitudinal grooves, which lodge the tendons that are inserted into the phalanges.

Phalanges. The pollex, or thumb, is a short, perfectly straight bone, which projects one inch beyond the abrupt termination of the crest-like elevation corresponding to the first metacarpal bone. It is much compressed laterally, and terminates in a truncated sharp edge. It is movably articulated with the metacarpal bone, but really has but very slight motion.

The third or "ulnar finger" is a single short, slight phalanx, about half an inch long. It proceeds from the extremity of the ulnar metacarpal, with which it is articulated, but is so firmly bound by ligaments to the under edge of the first phalanx of the larger radial finger that it enjoys little or no motion.

The middle or "radial finger" forms the proper continuation of the hand. It consists of three phalanges. The first is of considerable size, being one and a quarter inches long, its radial side thick and flat, and separated by quite distinct borders from the thin lamelloid expansion on its ulnar aspect. Its proximal end articulates with the distal extremity of the metacarpus by a slightly depressed and irregular surface. The second phalanx is much smaller, though of about the same length as the preceding, from which it differs chiefly in not having the compressed lamella of bone proceeding from its ulnar aspect. It articulates with the preceding by an enlarged head. The third phalanx is merely a very small, insignificant, acutely pointed spicula of bone, scarcely a third of an inch long.

Ossa innominata. The innominate bones are remarkable for their great length antero-posteriorly, as well as for their extreme narrowness and the straightness of their longitudinal axis, which latter is scarcely more curved than is that of the sacrum itself. They measure, from the tip of the ilium to the tuberosity of the ischium, six and a half inches; and they extend from the interspace between the sixth and seventh ribs to that between the second and third coccygeal vertebræ. Throughout this extent, they are very closely apposed to, and lie parallel with, the spine ; and they are completely anchylosed with it, except for about half an inch at each extremity. Besides the want of antero-posterior curvature, the bones — leaving out of consideration the rami of the pubes, which are curved towards each other on the median line — have little or no lateral convexity. They converge towards each other on the spine, at an angle of about 50°, forming a greatly elongated, very narrow pelvis; which, by the flattened shape of the ischia is quite deep and transversely triangular posteriorly, but which, more anteriorly, by the termination of the pubes at the acetabula, and the outward expansion of the ilia, becomes so shallow as quite to lose its characteristics as a "cavity." On the median line, the ilia, as usual in the class, do not meet, but are throughout separated by the anchylosed spinous processes of the sacral vertebræ. The approximation of the two cristæ ilii is greatest just posterior to the ischiadic foramen; both anterior and posterior to this point the bones slightly recede from the median line of the vertebræ, the amount of divergence gradually increasing, until the tips of the ilia are three fourths of an inch, and the tubera ischii one half an inch, from the median line.

Ilium. This portion of the os innominatum is, anteriorly to the acetabulum, a very thin, narrow, osseous prolongation, extending forwards and a little outwards as far as the seventh rib. It is externally concave antero-posteriorly, and also laterally very slightly so. It is completely anchylosed, to within less than one half an inch of the tip, with the transverse processes of the sacral vertebræ over which it is imposed. It has no connection, however, with the last ribs, though these pass out so close beneath it that they almost touch its internal surface. Towards the acetabulum the bone spreads out as a stout curve, which meets a similar projection from the ischio-pubic bone, and then completes the circle of the acetabulum. Just above the ring, the acetabulum proper, the bone becomes very thick and strong, and is elevated into a projection which overhangs as it were the cotyloid cavity. This eminence is suboval in shape; and bears upon its summit a flat, smooth, articular facet, continuous with the articular surface of the acetabulum proper, to which is apposed the superior surface of the trochanter major of the femur. The ilium posterior to the cotyloid cavity continues along the spine as a simple prolongation of bone for about an inch, after which it is completely fused with the ischium for the rest of its extent. The ordinary ischiatic notch of man is thus converted into a foramen. The foramen in this instance is of an oval shape, three fourths of an inch long, by one third in diameter, lying mesially to the obturator foramen at its commencement, just posterior to the cotyle, and close to the spine.

Ischium. The ischium is quite flat, scarcely presenting a concavity or convexity in any direction. Its mesial border is completely fused with the ilium, except anteriorly where it separates from that bone to form the ischiatic foramen, and runs forward as a slender process, separating the ischiatic from the obturator foramen, to the acetabulum, which as usual it assists in forming. Posteriorly, the bone is prolonged, forming quite a long and narrow but stout process, terminating in the tuber ischii, lying close alongside of the transverse processes of the two first coccygeal vertebræ, but not united with them. Between this projection and the process which curves forwards and outwards to meet the pubes there is a deep semilunar sulcus. The external border of the bone is long and concave, the latter especially at its extremities, — this concave border forming the mesial margin of the obturator foramen.

Os pubis. This is a long and exceedingly slender bone. Its anterior extremity, which contributes its share in the formation of the acetabulum, is tolerably broad and strong; but the bone immediately becomes contracted to a slender straight spiculum, which extends between the acetabulum and the projecting process of the ischium, forming the external border of the obturator foramen. With the tip of this projecting process, which seems to represent in part at least our "ascending ramus of the pubes," the bone is movably connected by ligaments. From this point the bone curves quite abruptly mesiad to meet its fellow. It becomes at the same time broad and thin, the breadth increasing suddenly towards the end, so that the bone terminates by a wide, rounded, club-shaped free extremity. As usual in the class, there is no symphysis pubis, though the two bones closely approach each other.

The shape and position, as well as the connections of the os pubis with the rest of the pelvis, are such that the free extremities of the bone must be approximated or separated chiefly by the *elasticity of torsion* of the slender shaft of the bone.

Acetabulum. The acetabulum has quite lost its character as a "cotyloid cavity." and become a simple ring of bone. The floor of the cavity is so entirely wanting, that the internal diameter of the acetabular ring is nearly as great as the external. The outer border of the ring is a well-defined, elevated osseous ridge,— most marked posteriorly and externally, but sinking somewhat towards the mesial line. The globular head of the femur is prevented from sinking through this ring by the abutment and articulation of its trochanter major with the prominent facet already described as lying above the cotyle. The smooth articular surface of the acetabulum is continued uninterruptedly on to this facet, so that the articulation of the head and trochanter of the femur is really only a single joint. The exact character of the motions resulting from this joint will be described in speaking of the femur.

Of the Lower Extremities.

In the upper extremities of the bird, although there is much interesting mechanism displayed, yet the various features are in general only such as are found in the wings of the greater number of the groups of the order. The very peculiar type of structure which stamps such an individuality upon the *Colymbidæ*, *Podicipidæ*, and, to a somewhat less extent, upon the brachypterous *Natatores* generally, does not extend in any very marked degree into the superior extremities. It is in the morphology of the posterior extremities, both as regards the osseous framework and the muscles by which the bones are moved, that we find the most marked peculiarities of structure. When we recollect how very peculiar are the form and position of the posterior extremities, both as regards the axis of the bird's body, and its centre of gravity, causing progression on land to be awkward and laborious from the stiff and constrained position in which the body must be placed to bring the centre of gravity within the base of support, we might naturally expect to find interesting peculiarities in the structure of these extremities. Such is really the case; the whole morphology of the posterior limbs being so moulded as to obtain the most advantageous structure possible for propelling the bird over and through the water, at a considerable sacrifice of ease and power of terrestrial locomotion.

This indication, which we see more or less completely fulfilled throughout the *Natatores brachypteri*, is perhaps more strongly pronounced among the *Colymbidæ* than in any other family of birds, with the exception of course of the Penguins, (*Aptenodytes*, *Spheniscus*, &c.,) and certainly reaches the maximum of development which is found among any birds that retain the power of aërial locomotion. The species of bird now under consideration being typical, so to speak, of the whole family, in it we can study this peculiar type of structure to great advantage.

In examining the morphology and functions of the lower extremities, we must of course consider them with reference to their action upon that element to which they are specially adapted, — the water. To produce a perfect pair of paddles, three indications must be fulfilled. First, the limbs must be articulated far backwards, and, while they have the freest motion, must be so abducted from the median line that the broad webs shall not interfere with each other. Secondly, in the backward stroke the broadest possible surface must be attained for action upon the water, while in bringing the leg forward exactly the reverse must be the case. Thirdly, the great power of the legs must be chiefly exerted in *pushing;* and hence the bulk of the muscles must be upon the posterior aspect of the several components of the legs. The mode in which this latter indication is fulfilled will be noticed in the description of the muscles. The first two may here be considered.

Femur. This bone is remarkably short and stout. It measures only two inches in entire length, while across the condyles it is three fourths of an inch, or more than a quarter of its total length. The width across the upper extremity, from the trochanter to the globular head, is fully half an inch. The shaft is also exceedingly stout, and much curved, the convexity presenting forward. It is marked along the entire length of its posterior aspect, as well as over the trochanter and on the sides of the condyles, with roughened tubercles and depressions for the attachment of the various muscles which act upon it.

The globular "caput femoris" is peculiar both in shape and position. It projects almost at right angles from the inner aspect of the proximal extremity of the bone. The neck, however, is so very short and thick, and projects so directly inwards, that the head appears to be little more than a stout process of bone. It is, moreover, placed so low down on the femur, that the great trochanter rises very considerably above its level. Its summit is as usual occupied by a fossa for the insertion of the ligamentum teres.

The trochanter extends upwards and outwards as a stout, somewhat pointed process, and is so large as to seem to form the real "head" of the bone; from the inner aspect of it the real head appears as a short stout offset. The non-articular surfaces of the trochanter are all roughened for the attachment of muscles. There is no trochanter minor.

The hip-joint is an exceedingly peculiar and interesting one, from the extent of the trochanteric articulation. The smooth articulating surface of the globular head of the bone is on the superior aspect continued uninterruptedly along the neck of the femur, to spread out on the top of the trochanter into a large, smooth, plane facet, which occupies nearly all the superior surface of that process.

When the head of the bone is inserted into the circular ring which constitutes the acetabulum, this articulating surface of the trochanter is applied closely to the smooth facet which, as already described, lies above and a little behind the acetabulum, appearing like a continuation from it, which in effect it really is. This abutment of the trochanter against the ilium prevents the small head of the bone from sinking too deep into the cotyle, which it would otherwise do from the very deficient character of this cavity; and, moreover, upon it seems to be borne the chief pressure of the weight of the body in some of its attitudes.

From this peculiar construction of the hip-joint, it results that a particular direction is given to the position, and all movements of the femur, and that motion in some directions must be exceedingly free, while in others it is greatly restricted, or wholly arrested. From the direction in which the plane of the trochanteric facet is situated, it results that the most natural and unconstrained position of the femur is outwards, forwards, and downwards, at an angle of about 45° in each of these axes. This remarkable outward position, or great amount of abduction, is necessary to enable the femur to clear the long ribs which project outwards and backwards along its inner aspect, and also contributes its share towards the wide separation of the feet. From this state of permanent abduction, any adduction, or any further abduction, are equally impossible; for the first would draw away the trochanter directly from its articulation, the latter would pull the globular head directly out of the cotyloid ring. Therefore, though muscles exist which arise from the horizontal ramus of the pubes and are inserted into the femur at various points, and which are really the analogues of our pectineus, adductors, etc., still, their line of traction, resulting from the shape of the pelvis and position of the femur, is such that they pull it almost directly backwards, having little if any adducting power.

Antero-posteriorly, the normal position of the femur seems to be in a state of semi-flexion forward at an angle of about 45°, with of course the divergence downwards and outwards before mentioned. From this position the movements of flexion and extension are quite free, the former particularly so.

The element of *rotation* is a very prominent one in the motions of the hip-joint, affording, as we shall presently see, the beginning of the very extensive power of rotation which the whole limb enjoys. A special muscle, the obturator, inserted into the tip of the trochanter, would seem to preside especially over the outward rotation; besides which various flexors, extensors, glutæi, etc., are made to act either as external or internal rotators, by some peculiarity in their insertion into the femur.

In the positions and movements of the femur we see its perfect adaptation to the functions it has to perform, — those of affording a short, stout *point d'appui* for the leg, at a sufficient distance from the body, and of powerfully impressing upon the distal segments of the lower extremity antero-posterior and rotatory motions; this *force* of motion decreasing as we proceed from the body just in proportion as *extent* of motion is augmented. It would not seem that the length of the first segment of a limb is an indication of the powers of that extremity. Thus among the *Cypselidæ* and the *Trochilidæ*, whose powers of flight are unsurpassed, the humerus is very short; but in them, as in the case before us of the Loon's femur, the primary segment is most powerfully acted upon by large muscles, which force of motion is by a common law of mechanics converted by the long distal segments into extent and rapidity of motion.

The distal extremity of the femur is no less interesting than the proximal. The shape of the two condyles, as well as of the articulating surfaces themselves, is very different. The external condyle is very much the larger of the two, projecting more outwards and as much further downwards than the internal one, as from the obliquity of the femur it is necessary to bring the faces of the two upon the same plane.[1] Its articulating surface is longitudinally very convex, transversely equally concave, by a rounded sulcus, which causes its convexity to present a ridge on each side. This is the true articular surface of the outer condyle, and it is closely coaptated with the head of the fibula. Upon the internal side of the condyle there is also, however, a facet of an oval shape, which articulates with a corresponding facet on the fibular edge of the head of the tibia. The proper femoro-tibial articulation is however with the internal condyle. The latter is much less irregular than the outer one, having simply an oval extremity, convex in both its axes, which rests upon the very slightly depressed, broad, flat head of the tibia. The movements of the knee-joint will be spoken of after noticing the bones of the leg.

Tibia. This bone is very long, measuring with its spine seven and a half inches, and consequently containing the length of the femur nearly four times. Its spine is just two inches long, leaving a length of five and a half inches for the tibia proper. Below, it is flattened antero-posteriorly, indicating its further expansion into the two condyles ("malleoli"). More superiorly, it becomes sub-quadrilateral. The outer posterior edge forms for nearly its whole extent the fibular anchylosis. The inner anterior edge is the most prominent. About one and a half inches below the head of the bone it rises as a very prominent thin crest, with a sharp margin. This crest curls over forwards more and more, until it has on its anterior aspect a deep longitudinal concavity, and, preserving much this shape, is prolonged two inches above the head of the bone as an exceedingly prominent spine. The posterior aspect of this spine is at its base prolonged directly from the articular head of the bone, forming a deeply concave continuation of the joint, exactly resembling the olecranon of the human species.[2] Indeed, this articulating surface of the tibia has almost exactly the shape and general appearance of the sigmoid cavity of our ulna. The

[1] Prof. Owen considers our olecranon to be not a patella joined to the ulna, but as rather analogous to the structure we are now considering.

[2] This difference in the length of the two condyles, to atone for the obliquity of the shaft of the femur, is precisely upon the same principle as in man, but the case is exactly reversed, — since, as the femur is permanently abducted, instead of adducted, the outer condyle instead of the inner must be the longest.

entire surface of the spine presents roughened elevations and depressions for the attachment of muscles. The oval concave head of the fibula, placed on the external aspect, completes the crural elements of the knee-joint.

Just at the superior border of the joint there is a very small projecting process of bone, which is generally regarded as the true analogue of the patella.

The twofold design of this elongated spine is quite evident. In the first place, by the simplest mechanical law, it increases greatly the power of the extensor muscle, the cruræus, coming down over the front of the femur. Secondly, some of the most powerful of the muscles which act upon the metatarsus take their origin primarily from its extreme tip, and the consequent increased length of fleshy bellies which they thus acquire gives them an equal increase of space for contraction.

The construction and movement of the knee-joint present several interesting peculiarities. Although both condyles of the femur articulate with the tibia, the most extensive articulation of the outer one is with the head of the fibula, upon which it principally rests. In this bird, however, while flexion and extension of course form the most prominent elements in the motion of the leg upon the thigh, to these there is superadded a very considerable degree of true rotatory motion, also quite different from the peculiar obliquity of motion which obtains in the elbow-joint.

The ordinary position of the leg, with reference to the axis of the body, when least influenced by muscular action, is to lie not very far from horizontally backwards, with some degree of inclination downwards, and a greater amount of obliquity outwards. When the leg is strongly flexed, it results, from the peculiar direction of the femur from the body and from the plane of the femoral condyles, that the leg becomes quite parallel with the axis of the body, while its outward inclination is totally lost. The legs in a fresh specimen may be easily made to touch each other over the coccygeal vertebræ. Conversely, with strong extension, the axis of the leg becomes more and more nearly perpendicular to the axis of the spine, while its amount of abduction from the body is constantly augmented. These are the positions consequent upon simple flexion and extension.

In the ordinary semi-flexed position of the leg, the plane of the condyles with which the metatarsus articulates, is placed obliquely outwards instead of directly forwards, so that the metatarsus projects outwards from the body; and the fibula, especially at its upper part, is rather upon the posterior than the directly external aspect of the leg. Now, when the leg is drawn forwards, the same muscles are so inserted that they cause a rotatory motion (chiefly in the knee-joint), which brings the fibula directly outwards, the plane of the tibial condyles directly forwards, — and consequently the sharp anterior edge of the metatarsus, and the anterior surface of the closed toes, cut easily through the water, with but slight resistance.

Although the femur participates in this rotatory motion of the lower extremities, yet the rotation is still greater in the knee-joint. From the construction of the joint, — remembering the broad flat head of the tibia on which the convex internal condyle rests, and the much more intimate coaptation of the head of the fibula with the external condyle, — it seems probable that the extremity of the fibula is chiefly the pivot around which the motion of the knee-joint takes place. Several muscles of the leg seem to act solely as rotators, while many of the flexors and extensors are so inserted as to have some such action.

The two condyles at the distal extremity of the tibia forming the "malleoli," are very prominent and convex, with a deep sulcus between them. They much resemble, in general appearance, the condyles of the human femur; but are laterally more compressed, and the sulcus between them is wider. It is remarkable that the internal one is the largest and longest, so that the obliquity of the tibia in relation to the axis of the body, instead of being corrected in the metatarsus, is increased, and the foot thrown still further outwards. On the posterior aspect, the condyles continue upwards for some distance, as prominent narrow ridges, serving to confine the very numerous tendons which pass down over the heel. The sides of the condyles are rough for ligamentous attachment. Just above the condyles, on the anterior face of the bone, is the depression ordinarily met with, crossed by a very distinct though small bridge of bone, forming a canal through which the extensor tendon of the toes passes.

Fibula. This is as usual a tapering bone, not extending the whole length of the tibia, and attached to its outer and somewhat posterior aspect. Its head is quite distinct, lying just at the edge of the head of the tibia, receiving the greater part of the outer condyle of the femur. For an inch or so, it is quite separate from the tibia; is then united with it for some distance, becomes again distinct for about an inch, and then finally merges as a slender spiculum into the side of the tibia, rather more than an inch above the joint. A slight crest, however, gives an indication of it, which can be traced quite to the external malleolus of the tibia.

"*Tarso-metatarsus.*" The next segment of the lower extremities results, as in most if not all birds, from the fusion of the elements of the tarsus and metatarsus proper.[1] In this species it is an exceedingly compressed bone three and a half inches in length; its sides nearly smooth and quite flat; its anterior and posterior borders grooved for the reception respectively of the extensor and flexor tendons; and separated from the sides by remarkably sharp edges. These edges are so prominent that they impress a very decidedly rectangular shape upon a transverse section of the shaft of the bone. By these grooves, and the fibrous thecæ, which their sharp edges give origin to, the tendons are prevented from encroaching in the least on the sides of the tarsus, which is thus enabled to keep its exceeding thinness; while at the same time they serve to increase greatly the antero-posterior width of this segment of the leg.

The process of bone representing the *os calcis*, rises at the superior end of the bone, on its posterior aspect, as a very conspicuous crest. It is of quite a regular square shape, about a third of an inch long, and of about the same height. The groove denoting its line of fusion with the metatarsus may be traced along its base. Into it are inserted the two tendons of the gastrocnemii; and its substance is perforated by longitudinal canals, through which pass the flexor tendons of the toes. The most posterior of these canals is very large, and transmits the majority of these tendons; anterior to it, that is between it and the metatarsus, are two or three very small canals, lying side by side on the same plane.

The proximal extremity of the bone is marked on each side of the median line by two oval depressions, in which are received the condyles of the tibia. In shape and position the two differ slightly from each other, in consequence of a corresponding difference in the two condyles of the tibia. On either side of the head are the roughened elevations for ligamentous attachments, and for the tendons of the tibialis posticus and peroneal muscles.

The metatarso-phalangeal articulation is extremely interesting. If we examine the foot of

[1] This segment is, by ornithological writers, universally called the "tarsus." Although this name is obviously incorrect, yet in our ordinary zoölogical descriptions of birds, it would seem hardly worth while to reject it in order to apply to it its more strictly proper designation of tarso-metatarsus.

the bird in a fresh state, we find, on closing the anterior toes, that they do not lie all beside each other; but that the inner one lies almost directly behind and between the other two. This arrangement of the toes is in order that the least possible resistance to the water shall be afforded by the toes when they are closed in the forward motion of the feet. To produce this effect, the inner of the three phalangeal heads of the bone is given off before the other two, and not by the side of them; but so far around on the inside of the metatarsus, towards its posterior aspect, that it lies almost directly beneath and behind the middle head. On looking at the bone directly from before, this head is quite hidden from view. In consequence of this arrangement, the line of the articulation of the inner toe is very oblique, to enable the toe to be extended without interfering with the one next to it.

The two other heads which form the distal extremity of the metatarsus, are placed side by side; the middle one being a little the larger and longer. They are very convex vertically, and each is marked with a median groove for the reception of corresponding median ridges on the heads of the phalanges. They are separated from each other by an exceedingly narrow but very deep furrow.

Just above the inner head of the bone, on its interno-posterior edge, is a slight oval depression, on which rests the accessory metatarsal bone. This is a small, thin, flat, falciform, almost unciform lamina of bone, entirely disconnected with the main bone, and simply applied loosely against it. It has no real articulation with the metatarsus; but its distal extremity is thickened for the support of the basal phalanx of the hallux.[1]

[1] I have recently been much interested in examining the very diverse modifications of this *os metatarsale accessorium*, both as regards its shape and its mode of connection with the metatarsus proper. To the end of ascertaining the amount of its variations in these respects, I have examined the hallues of many families and genera; in which labor I have been greatly assisted by my friend, Mr. A. E. Verrill, of Cambridge, Mass., who has taken the trouble to examine many forms which I had not at hand. The result of our observations shows that throughout the *Natatores*, and to a less extent among other *Aquaticæ*, the bone deviates most remarkably from the ordinary type, as presented by the higher orders of *Raptores*, *Insessores*, *&c*. Instead of being very intimately connected with the metatarsus, or even more or less completely anchylosed with it, and consequently immovable, and of a shape and general appearance which unmistakably point to its true character, this metatarsal element becomes totally disconnected with the metatarsus except ligamentously, and is therefore quite loose and freely movable; in some instances there is a smooth articulating surface, which may not impossibly be even lined with synovial membrane, while a frequent elongated and cylindroid shape of the bone itself, joined with its other characteristics, gives it the appearance rather of a third phalangeal segment.

It appears to be among the *Totipalmi* that the bone receives its most peculiar modification in size, shape, and connection. In *Sula*, *Pelecanus*, *Graculus*, &c., this metatarsal bone is nearly as long as the basal segment of the hallux, slightly curved, and of a cylindroid shape. Its proximal extremity has not the perfect articulating surface which its distal end bears; but nevertheless it is smooth, and nearly gives the impression of an articulating facet. Its character as a metatarsal element is greatly over-balanced by its phalangeal features, so that it is only by analogy that we can determine its proper place.

Throughout the *Laridæ*, this bone is found as a small, flattened, rounded, or irregularly polyhedral osseous nodule, very loosely connected with the metatarsus, and again presenting the appearance of a third phalanx, it being half as long as the real basal phalanx. In the anomalous genus *Rissa*, usually described as "tridactyle," both this bone and the proper basal phalangeal segment, are present and quite distinct; the ungual segment being the deficient one.

There is a remarkable peculiarity in the hallux of *Puffinus*, *Thalassidroma*, and probably most of the other genera of the large family *Procellaridæ*. This is, that while the accessory metatarsal is present, the true basal phalanx is wanting. Professor Owen, indeed, says (Todd's Cyclop., p. 288,) that "In the Petrel, however, this accessory metatarsal bone is wanting, although the hallux is present; the two bones of which, are therefore united to the principal metatarsal bone by long ligaments." But, as suggested by Professor Wyman, it seems most rational that in such doubtful cases as the present, we should be guided in forming our opinions chiefly by the shape and position of the bone; and that, too, even if a capsule and synovial membrane exist, as is probably the case in *Graculus*. The bone in the genera now under consideration, has much the characters and general appearances which obtain throughout the allied family *Laridæ*; which would seem to indicate correctly its real nature.

The whole subject of the number of phalanges and their peculiarities in the class *Aves*, is an extremely interesting one, and well worthy of extended investigation. Since the announcement by Cuvier of the normal number of phalanges and of phalangeal segments among birds, the matter does not seem to have received the attention it merits, perhaps on account of the well-known remarkable homogeneity of structure which obtains throughout the class. But I am of opinion that concerning this particular point there probably remain many anomalies, or at least peculiarities, yet to be brought into notice. Writers have not generally in their tables given, by any means, the whole number of the exceptions to the general rule, that are now well known to exist.

Phalanges. The four toes possess the number of segments which normally exist throughout the vast majority of birds; to wit, 2, 3, 4, 5, counting from the hallux to the outer toe. Some special features of each may be noticed.

The hallux is of very moderate length, though comparatively longer than that of many other families of *Natatores.* Its two segments, together with the claw and accessory metatarsal, only measure one and a third inches. Its basal segment is long and very thin, and compressed; its ungual is scarcely more than an osseous nodule for the support of the claw. Although this toe is not without its tendons, it appears to possess little motion, beyond what may be imparted to it by its membranous connections with the next one. It is furnished with a dependent lobe.

The second toe is chiefly remarkable (besides its peculiar articulation with the metatarsus already noticed) for the great length of its basal segment, which considerably exceeds that of the other two segments combined.

All the phalanges of the middle toe are very stout and strong, much surpassing those of either the inner or outer toes in this respect. It is intermediate in length between the inner and outer toes.

The outer toe is the longest of all. Its fourth segment, the penultimate one, presents the peculiarity of being considerably longer than either the second or third.

The mechanism by which the toes are separated from each other, or abducted, at the same time that they are extended, forms an interesting feature in the feet of this and other birds. The metatarso-phalangeal articulation is a strict ginglymus, not admitting of lateral motion, nor of rotation. But the median grooves of the heads of the metatarsal bone, instead of running directly perpendicularly over the joint, are placed a little obliquely; *i. e.*, that on the under head runs upwards and inwards; that on the middle head slightly outwards; that on the outer head is much more oblique. The planes of the heads of the metatarsus are also peculiarly twisted; so that on their inferior aspects they all look towards each other; but as they mount upwards, gradually turn outwards or away from each other. Now the heads of the phalanges, when raised by the extensor tendons over the joint, follow the direction of these oblique planes, being guided by their median ridge which fits in the median sulcus in the metatarsal bone; and so, by the time they are fully extended they also all look away from each other; and the webs are by this means spread.

Thus the toes when extended must also be carried from each other; and they cannot be approximated except when flexed. The intention of this peculiarity is evident. The more forcibly the toes are pressed against the water the wider their webs are spread by the resulting separation of the toes; whereas if the toes could be approximated when in a state of extension, it would require constant effort to preserve the expansion of the webs.

Myology.

Cutaneous muscles. The principal of these is the large muscle which lies immediately beneath the skin of the neck and breast, so closely adherent to the skin as to be taken off with the latter in ordinary skinning. It has quite an extensive origin on the breast, extending two or three inches on each side of the median line. The greater number of its fibres converge to pass up on each side of the median line of the neck, as narrow slips; but a thin, yet compact layer of longitudinal fibres completely encircles the neck, reaching quite to the occiput.

A pair of musculo-tendinous slips arise by three separate digitations from near the extremities of the fifth, sixth, and seventh vertebral ribs; these digitations converge, and pass upwards and backwards to be inserted into the skin just over the apex of the scapula. These muscles are apparently offsets from the serrati magni.

Another pair of musculo-tendinous slips pass to the skin, from the muscles just external to, and an inch below, the acetabula.

Muscles of the Trunk.

These need detain us but for a moment; their arrangement is as usual exceedingly complex, and probably presents no special peculiarities. It is only necessary, therefore, to notice the general features of the muscles of this region.

The head of the bird is large and heavy, and its neck comparatively long. From the tip of the bill to the first rib, measures more than from the latter point to the end of the coccyx. In flying, as well as in diving and swimming under water, this ponderous head and neck are held straightly outstretched. To enable the bird to do this, and to execute the varied and extensive, as well as exceedingly rapid movements of the head and neck necessary to secure its living prey, the muscles acting upon these parts are well developed. Their general disposition is as follows: —

On the back the opisthotenar muscles commence about opposite the crests of the ilia, and extend along the fossæ on each side of the spinous processes of the vertebræ. But as there is very slight mobility of this portion of the spine, the muscles are comparatively small and flat, and are moreover tendinous for a considerable portion of their extent.

On the back of the neck, just anterior to the shoulders, where the greatest strain from the weight of the head and neck is experienced, the aggregate bulk of the muscles is exceedingly extensive, much greater than at any other point along the spine. They are also almost wholly carneous, each of the numerous slips being muscular rather than tendinous, almost from their very origin. This is the point where the greatest mobility is required, as well as the greatest strength; and the two indications are fulfilled by the preponderance of the contractile over the non-contractile portions of the muscles, together with the increase in actual bulk of the muscular tissues.

Passing along the neck toward the head the bulk of the muscles decreases, and they become more tendinous, to the middle, but from this point toward the head their size and fleshiness again increase, until near the occiput the aggregate volume of the complexus, trachelo-mastoideus, &c., amounts to nearly as large a mass as is found at the root of the neck. This is necessary for the adequate support of the large and heavy head.

Biventer cervicis. The pair of muscles thus homologized by comparative anatomists, and which exists so constantly throughout the class, is very distinct in this species. Throughout their whole extent they receive no slips, and have no accessory attachments. They arise from the spines of the lowest cervical, or anterior dorsal vertebræ, as two slender round fleshy bellies; their central tendons are two or three inches long, after which the muscles again become fleshy, and as such are inserted side by side into the superior extremity of the occipital spine. The muscular portion thus considerably exceeds the tendinous.

The other individual muscles of the neck do not require special mention in this connection.

The muscles moving the caudal extremity of the spine, do not present any special peculiarities, with the exception of the *cruro-coccygeus*, or "*femoro-coccygeus*." This, from its origin and relations, may be more conveniently considered in connection with the muscles of the posterior extremities.

Of the abdominal muscles, the *obliquus externus vel descendens* is particularly remarkable for its extensive origin, which causes it to form an investment, not only of the abdominal, but also of the greater part of the lateral thoracic parietes. It arises by broad aponeurotic digitations from the retrocedent processes of about seven ribs; from the margins of the ilium; from the horizontal ramus of the pubis; and from the posterior margin of the sternum, overlying a great part of the broad xiphoid cartilage; its fibres (as usual in the class) are directed inwards, with but a moderate inclination downwards; and continue carneous almost to the median raphé, there being but a short aponeurosis before the insertion into the "linea alba."

Muscles of the Upper Extremities.

Pectorales. A remarkable peculiarity of the great pectorals is that they are united with each other by an extensive band of transverse fibres which pass across from one to the other just anterior to the keel of the sternum, lying upon the clavicular symphysis, and covering these bones for an inch or more.

The fleshy mass commonly called the "*pectoralis major*," consists of three portions, so very distinct from each other, in their origins and insertions, as well as in the motion they impress upon the humerus, that I prefer to consider them as distinct muscles. They are more distinct than the three *glutæi* of the human subject.

The first pectoral, or "*pectoralis maximus*," is large, long, and broad, but very flat, and not thick. It arises from the whole of the clavicle; from the lower half of the fibrous septum which stretches vertically above it; from the side of the keel of the sternum (except that part occupied by the succeeding); and from the edge of the sternum all around, as high as the articulation of the last sternal rib. The mass laterally overlaps the edges of the bone; posteriorly is continuous with the fibres of the abdominal muscles. In the middle of the muscle is a broad longitudinal tendinous septum, which divides the mass into a greater portion, with origins as above, and a smaller part, which arises from an oblique ridge upon the face of the sternum. The fibres converge without twisting to the ordinary insertion.

Pectoralis medius. Arises from the inner half of the anterior third of the keel of the sternum (all that portion not occupied by the preceding); from the sternum itself as far as an oblique ridge which runs from the sterno-coracoid articulation to the keel, and separates this muscle from the next; and from the upper half of the supra-clavicular fascia. Its fibres converge to pass under a large trochlear surface of the coracoideum (converted into a foramen by the apposed clavicle) to their insertion by a stout rounded tendon into the ridge of the humerus near its extremity.

It is a powerful external rotator of the humerus; and its further action elevates the humerus directly from the back, carrying its distal extremity in the arc of a vertical circle toward the head.

Pectoralis minimus. Situated posterior and just external to the preceding, this muscle arises from the outer half of the broad base of the coracoideum, and the contiguous portions of the sternum. It is much smaller than the preceding, with the posterior border of which its anterior border is parallel and in apposition. It runs forwards and outwards, and is inserted directly into the internal tuberosity of the humerus.

It adducts the humerus toward the body, and also depresses it when elevated.

Latissimus dorsi. The two portions into which this muscle is divided are perfectly distinct as to their origin, direction, and insertion. The anterior portion is a narrow, thin, delicate, ribbon-like muscle, arising from the spines of about three vertebræ opposite the middle of the scapula; passing directly outwards, over the scapular muscles, superficial to them all, it is inserted into the back part of the humerus, two inches below its head, opposite the insertion of the deltoid, close by the insertion of the posterior slip of the same muscle.

The posterior division of this muscle, larger than the preceding, and broad and fan-shaped at its origin, arises from the last four or five dorsal vertebræ; its fibres rapidly converge, and it is inserted into the humerus close by the side of the preceding portion.

These muscles draw the humerus directly backwards, slightly rotating it outwards.

The scapula is connected with the spine by the two layers of muscular fibres, — the *trapezium* and *rhomboideus,* — as usual in the class. The fibres of the two planes decussate at right angles, in the ordinary method.

The *serratus magnus* is very small and inconspicuous, arising by three digitations only, passing upwards and forwards, to its usual insertion into the apex of the scapula.

Muscles of considerable size, the homologues of the *teretes, infraspinatus* and *subscapularis,* proceed from the whole length of the scapula, below the origin of the extensor of the fore-arm to their insertion into the outer and posterior aspect of the head of the humerus. They rotate inward, and retroduct the humerus.

The *supraspinatus,* smaller than the preceding, and quite distinct from them, arises from that portion of the scapula above the origin of the extensor cubiti; and passes as a rather broad and thin muscle, to be inserted into the back of the shaft of the humerus, one and a half inches below its head, by a thin tendon, fully an inch in breadth. It rotates the humerus slightly outwards, and directly retroducts it.

Deltoid. Arises just at the coraco-clavicular articulation. It is small and weak, only about one and a half inches long; it passes directly over the shoulder joint, to be inserted into the distal extremity of the external humeral crest.

Immediately over the deltoid, and lying superimposed upon it, is the origin of the *extensor plicæ alaris.* As this muscle passes over the most elevated portion of the humeral crest, it gives off a tendinous slip which is inserted into the crest, after which it passes on to its insertion into the anti-brachium and metacarpus.

Biceps flexor cubiti. This is rather a "biped" than a "biceps" muscle; having apparently but one origin, and two insertions. It arises from the tip of the coracoid; passes as a rounded tendon along the depression between the anterior tuberosity and external oblique ridge of the humerus; continues single to the end of the first third of the humerus, where it divides into two fleshy bellies. The larger of these is inserted by a long round tendon into the tuber radii; the other seems lost in the fascia of the forearm; being also intimately blended with the fascia over which stretches the cutaneous fold at the bend of the elbow.

A small muscle arises from the anterior aspect of the humerus, about half an inch above its condyles; passing down mesiad of the tendon of the biceps, between it and the pronator radii teres, it is inserted into the inner border of the ulna, an inch or more from its head. This muscle lies more upon the forearm than upon the arm; its whole action, however, is that of a flexor of the forearm; thus being perhaps analogous to the *brachialis anticus.*

The *triceps extensor* of the forearm is divided into two perfectly distinct muscles, which may be called the "long" and "short." The former arises fleshy from the scapula half an inch below the glenoid fossa, passes as a stout, fusiform, fleshy belly to within an inch and a half of the olecranon, where it becomes tendinous; runs through a groove in the outer condyle of the humerus, to be inserted into the olecranon on its radial aspect. About an inch from its origin it gives off a small but distinct flat tendinous slip, which passes obliquely upwards and backwards to be inserted into the humerus; it being joined by a similar slip given off by the latissimus dorsi, which is inserted with it.

The other portion of the extensor is perfectly distinct, having a different origin and separate tendon of insertion. It arises from the posterior aspect of the shaft of the humerus for nearly its whole length; becomes tendinous near the elbow, and passing through a separate groove in the inner condyle, is inserted into the corresponding side of the olecranon, just opposite the insertion of the longer extensor.

Pronator radii teres; Supinator brevis. Arising respectively from the internal and external condyle, these two muscles converge towards their insertions into the radius exactly opposite each other. They directly antagonize each other; but, from the almost complete absence of pronation and supination in a bird's antibrachium, probably act together, and thus serve to steady the radius.

Extensor metacarpi radialis longior. As usual, a large muscle, the first one given off on the radial aspect of the limb. Arises high up on the external condyle by a flattened tendon, which soon changes to a fusiform fleshy belly; again changes, about the middle of the forearm, to a rounded tendon; this passes along a deep groove in the head of the radius, to be inserted into the radial aspect of the metacarpus. In its passage along the radial groove it is accompanied by the tendon of the next muscle.

"*Extensor metacarpi radialis brevior.*" (*Extensor proprius pollicis?*) This very slender small muscle arises from, and lies along, the ulnar aspect of the radius, its delicate tendon passing forwards along the radial groove with that of the preceding, to be inserted into the base of the pollex. Its tendon is more or less blended with that of the preceding; and any motion which it can impress upon the pollex must at best be but slight. It appears to have rather the effect of an auxiliary extensor of the metacarpus, aiding the action of the preceding.

A small, very slender, but long muscle arises from the internal condyle; lies along the ulnar aspect of the radius, beneath the preceding; its delicate rounded tendon passes through a notch in the head of the ulna, and runs obliquely along the side of the metacarpus; divides into two slips, one of which goes to the base of the pollex, the other to the base of the first digit. This muscle adducts the thumb, and bends the metacarpus upon the anti-brachium.

Flexor metacarpi radialis. Arises from nearly the whole length of the radial aspect of the ulna, and from the inferior aspect of that bone for its distal fourth. Its tendon passes obliquely over to the head of the radius; and is received into a deep groove, which carries it transversely across to the outer aspect of the wrist joint, where it dips deeply down to its insertion into the head of the metacarpus. This muscle seems to act as a flexor in the following interesting manner: When the hand is extended, or rather abducted, the head of the metacarpal bone, revolving in the radio-carpal articulation, carries with it the tendon, by which means the muscle is put upon the stretch. The contraction of the muscle, therefore, will of course tend to restore the bone to its original position, and thus fold or adduct the pinion.

Flexor carpi ulnaris. Of moderate size, fusiform shape, fleshy for nearly its whole extent; lying along the inner aspect of the ulna, its tendon inserted into the ulno-carpal bone, just in the angle of the wrist joint. It is a direct flexor or adductor of the metacarpus.

The phalangeal flexors and extensors do not seem to require special notice.

Muscles of the Lower Extremities.

As might be expected from the peculiar formation of the bony framework of the lower extremities, and especially the shape of the pelvis, the muscles of this part of the bird present many interesting features, as regards size, shape, position, line of traction, etc. From the great length, and extreme narrowness and flatness of the pelvis, the muscles proceeding from it to the femur and tibia, or fibula, are of peculiar shape, and have frequently unusual actions upon the bones they move. Thus, the line of traction of the pubo-femoral muscles is such, that their action as femoral adductors is almost entirely lost, and they have become rather extensors of the thigh. Other muscles again, ordinarily flexors or extensors, seem to exert their chief action in producing the rotatory movements of the leg and foot upon the thigh which in this genus are so perfect and extensive. From the extreme tenuity of the sacrum, several muscles seem to take their origin from the spine itself rather than from the pelvis. From these peculiarities of position and action, I have found considerable difficulty in homologizing several of the muscles. I have generally noticed them in the order in which they successively appear in the prosecution of the dissection.

Sartorius. The first muscle given off to the lower extremities, arises apparently from the spine of the dorsal vertebra about opposite the apex of the scapula; passes downwards and outwards at an angle of 45°, overlying the *latissimus dorsi,* of a uniform width of about three fourths of an inch, to be inserted, by a flattened tendon, into the inner aspect of the projecting spine of the tibia, half an inch *above* the joint. It is fleshy throughout, except just at its origin and insertion.

It is a powerful internal rotator of the leg; and to a less degree, an extensor.

A broad, thin, fan-shaped muscle, the "rectus femoris," as homologized by most comparative anatomists, arises from the median line of the sacrum for a distance of four inches, commencing just below the origin of the preceding, with the lower border of which its upper border is parallel and in contact; lies superimposed upon the vasti, glutæi, and cruræus; its fibres pass directly outwards, converging from this extensive origin to a narrow flat tendon, which passes over the external condyle of the femur, to be inserted into the head of the fibula. The muscle is tendinous for an inch or more at its insertion, and just at its origin; otherwise fleshy.

It is a perfect external rotator of the tibia, and therefore the antagonist of the preceding. From its insertion and the direction of its fibres it can have little or no effect as an extensor. Its shape is such that with its fellow of the opposite side it forms a perfect *trapezium* across the back of the pelvis.

Biceps flexor cruris. A thin fan-shaped muscle, not unlike the preceding in shape, arises from the pelvis near the median line, from opposite the acetabulum as far down as the tuber ischii, being therefore partially overlapped by the preceding muscle. From this extensive origin of about three inches, the fibres proceed directly outwards, converging to a flattened, then to a rounded, tendon. This tendon passes through a perfect fibrous loop, given off from the femur, (to be more particularly described hereafter,) by which its direction is changed; now passing with a considerable degree of obliquity downwards, it is inserted into a tubercle on the outer aspect of the fibula, one and a half inches below the knee-joint.

A direct and powerful flexor of the leg. In the passage of its tendon through the fibrous loop, and the consequent change in the direction of the line of traction, is seen a beautiful mechanism by which the force of the stroke as well as the extent of motion is increased when the backward movement of the leg is nearly completed; *i. e.*, at the moment when the most vigorous impulse is requisite. This muscle is doubtless the biceps flexor, from its insertion and mode of action, though there is nothing at all bicipital in its shape.

Glutæi. Filling the concave dorsum of the ilium, and lying close along the spine, is a mass of muscular tissue, which on its vertebral aspect is intimately blended with the spinal muscles proper, and with which some of its fibres appear superiorly continuous. I found it impossible to determine exactly the limits of the attachments of this muscle. It is incompletely divisible into two portions, which are however intimately united anteriorly. The largest of these — that nearest the spinal column — passes backwards to be inserted into the great trochanter; the other lies nearly parallel, but its tendon is inserted further down on the outer and anterior aspect of the femur.

The first of these muscles evidently rotates the femur inwards. The other is directly in the line of flexion; and though it cannot have much power, from its high insertion into the femur, it probably aids to flex, and somewhat inverts that bone. These muscles seem from their position and insertion, to be the *glutæus medius* and *minimus*, though from the peculiar shape of the parts, their actions are not identical with those of the human species.

The muscle which probably represents the *glutæus maximus* is quite distinct from the others and smaller than either of them; and from the elongated shape of the pelvis, is entirely *caudad* of the femur, instead of lying in the same region and obliquely in the same plane with the other glutæi. It is a small flattish muscle, one and a half inches wide, lying close along the sacrum, on the pelvis, from an inch above the tuber ischii, to the femur. Its tendon runs forwards and obliquely outwards from the spine, to be inserted into a tubercle on the externo-posterior aspect of the femur, just below the trochanter, and just opposite the insertion of the above described *glutæus minimus.* The whole origin and inferior surface of the muscle is fleshy; but its tendon of insertion continues along its external surface to within an inch of its origin.

As in the human species, this muscle extends and everts the thigh. It directly antagonizes the *glutæus minimus.*

Obturator. The obturator foramen is filled by a muscle which arises from its whole circumference, lying between two layers of fasciæ. The small rounded tendon of this muscle runs forwards to be inserted into the posterior aspect of the great trochanter. It directly rotates the thigh outwards.

Cruræus. A large muscular mass, lying upon the anterior aspect of the femur. Instead of converging to a tendon for its connection with the tibia, it has a very extensive muscular attachment to the posterior face of the whole length of the tibial spine that projects above the knee-joint.

This is the direct extensor of the leg. Although so short, only as long as the short femur, yet its action must be powerful, from the amount of contractile fibre it contains and from the great increase of leverage obtained from the projecting spine of the tibia.

Vasti? On either side of the preceding lies a smaller muscle, having its origin from the femur near its head. They proceed over the femoral condyles to be inserted respectively into the inner side of the head of the tibia, and into the head of the fibula close to the articulating surface.

From the origin and position of these muscles, they seem to represent the *vasti;* but by a slight variation in their insertion, their function is entirely changed. They can exert but very slight, if any, action as extensors of the leg. They are *rotators* of the leg upon the thigh. The internal one acts conjointly with the sartorius; while the external one is intimately blended with the tendon of the broad fan-shaped muscle, above described, and referred to the rectus femoris.

It will thus be seen, that of the four muscles which in the human species conjoin to form a "quadriceps extensor cruris," only one, the cruræus, is here left as a proper extensor. The rectus joins the vastus externus, and both are together inserted into the head of the fibula, to act rather as external rotators; while the vastus internus forms an internal rotator, in which action it is assisted by the sartorius.

The "pubo-femoral" muscles, — the proper adductors of the thigh, — are represented by a broad plane of muscular fibre, which arises from the whole length of the horizontal ramus of the pubes, and from a considerable portion of the obturator fascia. From this extensive origin the muscle converges as a thin flat plane, to be inserted by a broad tendon into the lower half of the femur. I was not able to divide these fibres into distinct muscles.

A large, somewhat flattened muscle arises from near the tuber ischii, and from the sides of the sacrum nearly as far as the femur; also from the surface of the pelvis not occupied by the glutæus maximus, which it overlies, and proceeds obliquely upwards and outwards, to be inserted into a tubercle on the inner and posterior aspect of the femur, a little below its middle. On the external surface, the tendinous portion of the muscle extends to within two inches of its origin; but on the internal aspect the muscle is fleshy, nearly to its point of insertion.

The first of the two preceding muscles is of course homologous with our adductors, and the latter would seem from its insertion to belong to the same class. But however this may be, the shape of the pelvis, and the relative position of the femur are such, that any action they may have as adductors can be but slight, and must be greatly overbalanced by their more energetic action as *extensores femoris.*

In connection with the muscle last described, there is to be noticed one belonging to quite a different set, viz. the "*femoro-coccygeal.*" This is a small, narrow, ribbon-like muscle arising from the base of the coccygeal vomer. It proceeds forwards, fleshy, for two and a half inches, changes suddenly to a small rounded tendon, which lies along the outside of the tendon of the muscle last described. They soon become intimately blended together, and proceed as one tendon to their insertion into the femur.

There is thus a strong "guy" proceeding on each side of the pelvis from the femur to the coccyx, reminding one irresistibly of the tiller-ropes of a boat's rudder. Acting together they serve to steady the tail; more strongly contracting, they draw it downwards; while either acting alone draws the tail obliquely downwards and to the corresponding side.

Semi-tendinosus. Arises from the tuber ischii, being at its origin intimately blended with the second of the two femoral "adductors" just described. It crosses obliquely over the coccygeal muscle; passes outwards and forwards, and is inserted by a narrow flat tendon into the tibia, about an inch below the joint.

Semi-membranosus. Arises from the pelvis about midway between the acetabulum and tuber ischii, and is inserted by a broad membranous tendon into the crest of the tibia just above the insertion of the preceding. It is a thin flat muscle, with a tendon fully as wide as the fleshy portion.

These two muscles are the proper flexors of the leg upon the thigh. Their tendons form the "inner hamstrings," and from their situations, relations, and uses are undoubtedly to be homologized with the *semi-tendinosus* and *semi-membranosus.*

In my dissections I failed to detect a "gracilis" muscle; or any connection of a tendon of a crural extensor with a digital flexor, by which flexion of the toes is produced by the mere bending the knee and ankle-joints, as is the case with the *Insessores,* etc. I do not think that such a mechanism exists, at least to any marked degree, although I may be mistaken.

Considering collectively the muscles which act upon the thigh and leg, it will be noticed that by far the greater part of their combined force is exerted to produce powerful *extension* of the thigh and *flexion* of the leg, with a free *rotation* of the latter upon the former; while the power of flexion of the thigh, and extension of the leg, is reduced in a proportionate degree. The importance of such a disposition of the muscular forces of the parts to the full development of vigorous natatorial power, is too evident to need comment; for the bringing forward of the leg requires but very slight effort in comparison with that necessary to produce the energetic backward stroke by which the bird is propelled forward. Now, in examining the muscles of the leg and foot, we shall find that they are so disposed as to most effectively continue the powerful backward stroke which began at the hip-joint. The extensors of the metatarsus vastly predominate both in number and size over the flexors. No less than seven tendons pass over the posterior aspect of the tibio-tarsal articulation, while only three are found upon its anterior face. I will notice the more important of these muscles.

Tibialis anticus. Arising from the very tip of the projecting spine of the tibia, and from the whole anterior aspect of that spine down to the joint, it lies along the face of the bone for its whole extent, though no more fibres take origin from it. It is fusiform in shape. Its tendon passes directly over the anterior surface of the joint, being bound down by a transverse ligament, and is inserted into the head of the metatarsal bone. It directly flexes the tarsus.

Extensor digitorum communis. Much smaller than the last, lying beneath and internally to it. It is somewhat penniform in shape, its tendon running up for some distance on its inner edge, its outer surface being covered with dense fasciæ. It arises from the anterior aspect of the spine of the tibia, down as far as the knee-joint, for which extent it is intimately blended with the muscles by which it is surrounded. After passing the joint, it becomes distinct from any other muscle; but fibres continue to take origin from the face of the tibia for nearly its whole length. Its tendon passes behind and internal to that of the tibialis anticus, passes through an osseous canal formed by the bony bridge which stretches across between the malleoli, and runs along the anterior edge of the metatarsal bone, in a deep sulcus; about half an inch from the end of the bone, it gives off the tendon which goes to the inner anterior toe; this at once divaricates in a special groove, while the tendon proceeds to the head of the metatarsal bone, just over which it splits into two for the middle and outer toes. The tendons extend to the bases of the last phalanges on each toe.

Peroneus. Much smaller than either of the others, this muscle arises from the fibula for the greater part of its length. Its tendon passes through a separate canal in the annular ligament, on the outer aspect of the joint, and proceeds obliquely backwards, to be inserted into the posterior border of the metatarsal bone, just at its base. From the peculiar position of the tendon where it is bound down, as well as by its insertion, it can have little or no effect in moving the tarsus backwards or forwards. When the tarsus is extended it may weakly aid in extending it; but its principal office is evidently to direct and restrict the rotatory movements of the tibio-tarsal joint. It quite powerfully rotates it outwards, and antagonizes the *tibialis posticus* on the outer side of the joint.

Gastrocnemii. In the *gastrocnemii* there is seen the same plan as was noticed in the "*triceps*" *extensor cubiti*, viz. — a tendency to divide into two distinct muscles. It is not, however, so strongly pronounced as in the former instance, though the three origins of the gastrocnemius are even more widely diverse.

The inner, or rather the anterior *gastrocnemius* lies upon the inner and anterior aspect of the tibia for its upper two thirds, afterwards crossing the leg obliquely, to get upon its posterior aspect. It has two heads; one arising fleshy from the apex of the tibial spine, from the whole anterior face of the upper two thirds of the bone, and from the fibrous septa between it and other muscles; the other from the inner condyle of the femur; the tendons of the *semi-tendinosus* and *semi-membranosus* being interposed between them.

The posterior or outer *gastrocnemius* arises from the "*linea aspera*" for nearly two thirds its length, and from the outer condyle; also receiving attachments from the muscle described as the *rectus femoris.*

These two portions of the muscle, thus diversely arising are fleshy to within two inches of the heel. There they change into two stout round tendons, entirely separate from each other. A little above their final insertion they fuse into one broad, thick, very powerful tendon, which passes directly over the posterior aspect of the joint, (overriding the tendons of the other muscles,) and is inserted into the base of the bony protuberance on the back of the metatarsus.

At the mesial edge of the insertion of the last described portion of the gastrocnemii, there proceeds down from the femur a most perfect sample of an aponeurotic loop. This loop encircles the tendon of the *biceps flexor cruris*, and changes the direction of its line of traction as much as does the loop which in our species binds down the tendon of the *digastricus* to the hyoid bone. It runs down from the femur as a distinct narrow fibrous band; embraces the tendon, and returns upon itself, the two ends of the loop being inserted side by side. This loop is more or less blended with the fibrous investment of the under surface of the gastrocnemius.

The dissection and examination of the remaining muscles of the back of the leg is exceedingly difficult. They are all more or less intimately united with each other, throughout the greater part of their muscular as well as tendinous structure. They arise from the outer and posterior aspects of the bone, and from the intermuscular septa between one another. They become tendinous at very various points. Their tendons, however, are all aggregated together to pass directly over the posterior aspect of the heel. Just over the joint, nearly all are enclosed in one large dense shiny white mass of fibro-cartilage, through which each tendon bores a canal for itself. Leaving this sheath, all but one (the *tibialis posticus?*)

pass through the canals of the bony protuberance which is superimposed upon the base of the metatarsal bone, and proceed to their different digital insertions. This bony canal is subdivided by osseo-cartilaginous septa into three divisions: a quite large central posterior one, through which the majority of the tendons pass; and two or three smaller latero-anterior ones, for special tendons. I will notice two of these muscles which are quite distinct as to their insertions, and consider the others collectively as the digital flexors.

Tibialis posticus? A muscle which I thus doubtfully homologize, not from its position, but from its insertion and evident action, arises from the very apex of the tibial spine, and from the fibrous septa between it and contiguous muscles. Its tendon passes with the others through the fibro-cartilaginous envelope; but then divaricates, to be inserted into the inner aspect of the base of the metatarsal bone. It is the evident antagonist of the peroneus already described; directing and limiting the rotation of the tarsus.

The inner anterior toe has a special flexor of considerable size. Its tendon passes over the back of the joint, through one of the smaller divisions of the bony canal; and proceeds to its insertion along a deep groove on the posterior edge of the metatarsal bone.

The *common flexors of the digits* as usual consist essentially of two sets, a *perforans* and *perforatus*, though the expressions "superficial" and "profound" do not here hold good, as they have no such relative position. The tendons of the two sets, however, do really lie superimposed upon each other, and the one divides for the passage of the other, much as in the human species. The interlacing of the tendons of the different flexors is exceedingly intricate. Almost every one sends tendinous slips to one or more of the others; so that the most simultaneous action of all the toes is secured; and though the fleshy bellies of some of the tendons have diverse origins, the combined effect of the whole seems to be that of a single powerful flexor.

Explanation of Plate V.

Fig. 1. — Superior aspect of skull.

Fig. 2. — Lateral aspect of skull.

Fig. 3. — Inferior aspect of skull.

Figs. 1, 3, are without the inferior maxillary. These three figures are of the natural size.

Fig. 4. — Pelvis and posterior extremities *in situ.* One half the natural size.

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VI. *An Inquiry into the Zoölogical Relations of the first discovered traces of Fossil Neuropterous Insects in North America; with Remarks on the difference of structure on the Wings of living Neuroptera.* *By* SAMUEL H. SCUDDER.

Read January 18, 1865.

IN the January number of Silliman's "American Journal of Science" for 1864, (vol. XXXVII., page 34,) Prof. J. D. Dana announced the discovery for the first time in North America of the fossil remains of Neuropterous insects. They were found in flattened ironstone concretions, which occurred in the carboniferous beds at Morris, Illinois, in company with various coal-plants and amphipod crustaceans. Two specimens only had fallen under his observation, which, in the Journal referred to, in an article entitled "On Fossil Insects from the Carboniferous Formation in Illinois," he has figured upon wood and briefly described under the names of *Miamia Bronsoni*, and *Hemeristia occidentalis*, the former after the name of the original discoverer of these important remains.

Through the repeated courtesy of Professor Dana, I have been permitted as long an examination as I desired of these interesting fossils, the results of which, and the comparisons I have incidentally instituted with allied groups of living insects,[1] I have now the honor to lay before the Society.

The specimens imbedded in these stones exhibit the insects in the natural attitude of repose, which, as in many other Neuroptera, is with the wings overlapping one another above the abdomen; in those Neuroptera which close their wings in this manner the right upper wing overlaps the left upper wing (or the left overlaps the right), while that again overlaps the right under wing, and this the left under wing; the result is that in certain places we have actually in a cross-section four thicknesses of wing with their accompanying nervures, which last, if of sufficient thickness and strength to give an impression through these four thicknesses, when compressed between layers of mud, would in a case like that of *Hemeristia*, where the cross-veins are quite heavy and numerous, present an almost inextricable network of veins, and render it a very difficult task to determine the neuration of any one of them. In *Miamia* the nervures are feeble, though the wing-tissue is apparently correspondingly delicate; and the wings not overlapping one another so completely as in *Hemeristia*, it is not so difficult a task to determine to which wing different nervures belong; yet were it not for the general similarity of the neuration in the upper and under wings in this sub-order, it would even here be a perplexing matter. In *Miamia* the abdomen is preserved, and the nervures crossing it leave no room for doubt that the insect is viewed from above; but in the specimen of *Hemeristia* we have the additional disadvantage that we cannot tell which surface we view otherwise than by the structure and relations of the wings themselves, which besides are but fragmentary, and exhibit in continuity but a small portion of the outer margin of a single wing and the inner border of none at all, the base and apex also being absent. We have then in *Hemeristia* — given the central portion only of four wings, completely overlapping one another, unusually charged with cross-veins reuniting the branches in every part, with no external means of deciding whether the upper or under surface is presented to the eye, to determine what is the exact structure of each wing.

[1] I would here express my obligations to my friend Mr. P. R. Uhler, for the kindness with which he has permitted me to use freely his extensive and varied collection of Neuroptera, containing many forms otherwise quite unknown to me.

Looking at the right side as being in this case more complete, and following the course of the vein which appears at the margin next the base, we see that at a little distance out it sends forth a prominent branch which has a peculiar curve. Now as we know that among Neuroptera neither the *vena marginalis*[1] or *mediastina* sends off branches in this way, we necessarily conclude that this cannot be either of those veins; and as it is quite what we might expect in the *v. scapularis* and is just so important a vein as that is, and as at one side we find two veins outside of this running parallel to one another and to this, closely connected by and frequently charged with cross-veins, which in this part of the wing is often characteristic of the *v. marginalis* and *mediastina*, we conclude that these three veins belong to one and the same wing, and are those of the outer margin. Glancing at the opposite side we see the same peculiar curved vein, which here also is quite prominent, though there are no veins outside of it, and we naturally conclude that this belongs to the corresponding wing on the other side, the outer veins of which have been destroyed. We may notice next that on the right side between the peculiar curved branch and the vein from which it springs there lies a vein running midway between the two and apparently connected with either by frequent cross-veins, which being quite an anomalous feature among Neuroptera, if our previous views were right, excites our suspicions; but knowing that it would be quite as great an anomaly were there to be four parallel veins along the costal-border thickly beset with cross-veins and similar in every respect, we look more closely to see if these may not belong to another wing, either above or below that to which the curved branch belongs. We notice, in confirmation of this supposition, that on the left side this dividing vein does not run midway, but considerably at one side; and observing the right side more carefully, we see that the cross-veins between the *v. scapularis* and its branch override the vein which runs midway between these two, which has also itself separate and less distinct cross-veins, connecting it with a vein which must be directly beneath the *v. scapularis*; and we therefore conclude, that the space thus covered by these less prominent cross-veins must be either the *area marginalis* or *scapularis* of the wing lying beneath; to determine which of these it is, we look for the homologue of the peculiar curved branch and find it taking its rise from this vein at a point similar in position to what we found in the wing above, and less conspicuous than there, not only as it naturally would be from lying beneath but proportionally less so, as is also the *v. scapularis* of the lower, as compared with that of the upper, wing. The area referred to is then the *area scapularis*, corresponding to the inner of the two narrow ones which lie outside the *v. scapularis* of the wing above. Now, as in Neuroptera, not to speak of other insects, the anterior half of the wing is more specialized, and contains stronger veins in the anterior wing than the corresponding portion of the posterior wing, which in its turn is generally more specialized in its posterior half, we conclude from the prominence of the *v. scapularis*, and its branch and cross-nervures in the wing which lie above, that they belong to the anterior wing, and that we view the insect from above. In very strong confirmation of this view is the fact that the *v. scapularis* of the wing above lies outside of, and yet parallel to, the *v. scapularis* of the wing below, proving, beyond a doubt, that the upper is the anterior wing; for the *v. scapularis* of the posterior wing could not lie outside of that of the anterior in any part of its course without crossing it or at least being divergent from it.

Pursuing, then, the same method of inquiry in regard to the other principal veins,

[1] See note 3 on p. 175, where these names are explained.

we discover that those of the right anterior wing cut across the principal veins on the left side which correspond to those of the right anterior wing, and therefore that the right wing overlaps the left. The position of each of the wings being then satisfactorily made out, it requires only patient examination and studied comparisons to determine of every one of the principal veins, or even detached [1] branches and cross-veins, to which of the four wings it belongs; [2] and being able thus to delineate the remnants of each of the four wings, and making up from one, so far as is proper, the deficiencies of another, and carrying our point somewhat farther into what is partly conjectural, but guided principally by our knowledge of the relations of this insect to the Neuroptera in general, we are able to reconstruct, more or less accurately, the complete structure of all the wings of this insect as partially figured in our plate.

But this is only one step; it is indeed but the starting-point. We have now merely a basis, but a firm one, upon which to stand in making our most essential inquiry as to the relation of these ancient types to the other members of the sub-order to which we saw at first they were allied. We need to investigate something of their more intimate relationship, and to know how much kinship these forms, which flitted through the oozy marshes of the carboniferous forests, had with the living realities of our own day.

To determine this point we have in the Hemeristia only the wings to guide us (except a fragment of a leg which is here of but little value), and must therefore inquire whether the different families of Neuroptera have anything in the structure of these parts which shall enable us by their aid alone to distinguish them from one another, and to determine of any wing-form presented to our eye, to which of these groups it belongs. If we can do so, we can ask of course, in reference to the fragments in question, whether they belong to any one of the hitherto described family groups, and to which,—or whether they must form another akin to them, but belonging to the same sub-order of Neuroptera. Inquiries made with a view to determine this point have convinced me that this is quite possible, and I have therefore embodied the results of my inquiry in the following statement of the distinction in wing-neuration among the families of Neuroptera.[3]

Termitina.

The *v. marginalis* and *mediastina* run parallel to the very tip of the wing and in close conjunction, apparently with no connection between them; the *v. scapularis* also runs parallel to the *v. mediastina,* though a little more distant from it, and is sometimes connected with it irregularly by many cross-veins, directed from the *v. scapularis* upwards and outwards; generally it forks beyond the middle though sometimes close to the base. The *v. externo-media*

[1] Detached by the incompleteness of preservation, for there appear to be none independent.

[2] It was only at the very last moment of examination that I discovered also the remnants of the *v. marginalis* and *mediastina* separated from the basal portion of the right anterior wing, but otherwise unbroken, lying entirely removed from the wing; and what is rather remarkable, an exactly similar fragment of the left anterior wing also entirely detached and lying at right angles to it; at the outer extremities of the first we can see faint indications of fragments of a femur and tibia at their union, which correspond pretty well, so far as can be determined, with what we find in Miamia.

[3] I have made use here of the terminology employed by Heer, in his memoirs on the fossil insects of Œningen, etc., as being more true than any other known to me, though I am not quite sure that the names are fitly chosen, to suit the homologies of wings of insects in general. He enumerates six under the following names: the first, counting from the upper border, the *vena marginalis;* second, *vena mediastina;* third, *vena scapularis;* fourth, *vena externo-media;* fifth, *vena interno-media;* sixth, *vena analis.* The spaces between the margin and the *vena marginalis* he denominates *area extra-marginalis;* that between the first and second veins, *area marginalis;* between the second and third, *area scapularis;* between the third and fourth, *area externo-media;* between the fourth and fifth, *area interno-media;* between the fifth and sixth, *area analis;* and that between the *vena analis* and the hind-border the *area externo-analis.*

is as distant from the *v. scapularis* as that is from the *v. mediastina*, and runs parallel to it, sending out many branches downwards and outwards, which fork indefinitely, the forks being never united by cross-veins; these fill up the remainder of the wing. The *area externo-media* is occupied by an independent vein, which is connected with the veins on either side by irregular cross-veins; both wings are alike. This is substantially the same account as is given of them by Heer, only that he considers what I have called the *v. mediastina* as the *scapularis*, the *v. scapularis* as the *externo-media*, and the *v. externo-media* as the *interno-media*, in which he may be correct.

Embidina.

In the *Embidina* the *v. marginalis* forms the anterior margin. The *v. mediastina* runs parallel and near to it till quite near the tip, when it is deflected downward and terminates at the *v. scapularis*, which in like manner, running parallel to the *v. mediastina*, turns abruptly downwards just at or beyond where the *v. mediastina* strikes it, and strikes the upper branch of the *v. externo-media*. The *v. externo-media* forks at a distance of one third or more from its origin to the tip of the wing, the upper branch running parallel to the *v. scapularis* till it strikes it, and then continues on in the same course to the tip; the lower fork is generally dichotomous. The *v. interno-media* is a simple vein running in quite a direct course to the margin; the *v. analis* is sometimes forked at the base, in which case the lower branch forms the hind margin of the wing, and the upper is generally simple and straight; cross-veins, very few in number, connect the *v. externo-media* with the *interno-media*, the branches of the *v. externo-media* with one another, the *v. externo-media* with the *scapularis*, and are found in the *area marginalis*.

Psocina.

Vena marginalis continuous; *v. mediastina* in the upper wing broken, in the under wing reaching the *v. marginalis*, a short distance from the base; *v. scapularis* occupying the greater part of the wing, being the only forked vein in the wing; near the base it sends out a branch abruptly downwards, which immediately turns and runs parallel to the main stem; the main stem, running in a straight course, reaches the margin beyond the middle, then deflects from it, and either strikes one of the branches of the other portion of the vein, or just before reaching it again turns abruptly upwards and strikes the margin; the main branch, running parallel to the main stem, sends out a branch at a wide angle just before the middle of the wing, which running in a straight line strikes the lower margin near the middle. Just below where the main stem reaches the upper margin, the main branch sends out another branch sub-parallel to the first, but sinuous, from which more than half way to the margin a widely spreading fork proceeds, the upper branch again and again forking widely. The main branch just beyond the origin of this second branch is itself deflected suddenly and sinuously downwards, running sub-parallel to the upper forks of the second branch, till it reaches the margin at the apex of the wing, but from the middle of its downward curve sending off a branch at right angles which forks and fills the space between the termination of the main stem and the main branch of this *v. scapularis*; at the middle of the wing a stout cross-vein unites the main branch and stem, and this is the only cross-vein in the wing. The *v. externo-media*, curving slightly with a convexity toward the apex of the wing, strikes the lower margin just behind the first branch of the main branch of the previous vein. The *v. interno-media* is but little separated from the *v. analis*, which simply forms the lower margin of the wing. In the under wing the variation is so great from this that the main branch of the *v. scapularis* separates as a widely branching fork from the main stem some little distance from the base, and continues straight on to the margin as the first branch did in the upper wing, the main branch being then a fork from this straight one, and branching as the main one did in the upper wing, except that it wants altogether the second branch.

Perlina.

The *v. mediastina* runs parallel and pretty near to the *v. marginalis* until somewhat beyond the middle of the wing, when it turns suddenly at right angles and strikes the *v. scapularis*, which has been running nearly parallel to it, though at a less distance from it, than the *v. marginalis*. The *v. scapularis* continues on parallel to the *v. marginalis*, and runs into it a little before it reaches the tip of the wing. The *area marginalis* is traversed by frequent cross-veins; the *area scapularis* has none. The *v. scapularis* gives off a branch generally half way between the base and where the *v. mediastina* strikes it, which running sub-parallel to the main stem terminates at about the tip of the wing, crossed at some point in its course by another vein from the *v. scapularis* which generally (exc. *Tæniopterix*, etc.) continues on and connects with the upper branch of the *v. externo-media*; the branch of the *v. scapularis* then divides into many branches, which are sometimes simple, sometimes again forked, and sometimes have, in connection with the branches of the *v. externo-media*, recurrent forks.[1] The *v. externo-media* runs in very close proximity to the *v. scapularis* a little distance, and then runs parallel to the branch, until it approaches the cross-vein from the *v. scapularis*, when it forks, the forks sometimes again reforking. The *v. interno-media* has a very indistinct attachment at the base, being seen only from the under side, — is distant from the *v. externo-media*, — has a considerable curve at its commencement, and very soon forks, the upper fork running distant from, but nearly parallel to, the *v. externo-media*, gradually separating from it until near the forking of the latter, when it curves towards it and unites to its lower branch; it sends off rather distant cross-veins to its own lower branch, and beyond emits many branches to the margin. The *area interno-media* is traversed sparingly by cross-veins, sometimes in the fore wing only. The lower branch of the *v. interno-media* is simple, and diverges from the upper branch as that from the *v. externo-media*. The *v. analis* is stout and forks at its origin; the space between the forks enclosed near to the base by a thick cross-vein which extends to the internal margin, and from mid-way between the forks sends out a branch which runs between them, any or all of which branches and forks may branch again, which they do to considerable extent in the hind wing, where also there are more branches from the cross-veins.

Ephemerina.

Fore Wing. The *v. mediastina* runs near, and parallel to, the *v. marginalis*, extending to the tip of the wing. The *v. scapularis* bears the same relation to the *v. mediastina*. The *v. externo-media* runs parallel to the *v. scapularis* for a short distance, and is at the same distance from it as that is from the *v. mediastina*; close to the base it sends out a branch, which forks when it has reached two thirds of the distance to the margin, the lower branch striking the outer margin at about the middle; at less than one third the distance to the tip of the wing the vein forks, the upper fork remaining parallel to the *v. scapularis*, while

[1] But in *Capnia* we have a very remarkable difference in that the main branch of the *v. scapularis* has its origin beyond the cross-vein from the *v. scapularis* to the *v. externo-media*.

the lower branch diverges rather widely from it, the space between being divided into equal distances by several independent veins. The *v. interno-media* starts from the same point as the former, and is simple. The *v. analis* is widely separated at the base from the previous, is much curved, first upwards and then downwards, and sends out several branches which curve as they are directed towards the margin. The veins and their branches are traversed everywhere by rather frequent cross-veins, but the wing is nowhere reticulated except slightly around the margin.

Hind Wing. Either the *v. mediastina* or *scapularis* is wanting, very probably the latter, as the *area externo-media* is very wide. The branching of the *v. externo-media* is nearer the base than in the fore wing; the *v. interno-media* is apparently wanting, and the *v. analis* is more uniformly curved.

Odonata.

Quite a characteristic feature of this group is that the *v. marginalis* extends but half way along the margin, and terminates abruptly; and that the *v. mediastina* runs nearly parallel to it, with a distinct space between them; when it reaches the point where the *v. marginalis* terminates it turns abruptly upwards, forming the "*nodus*," and protects the rest of the margin. The *v. scapularis* runs parallel to the *v. mediastina* as far as the nodus, is there connected by a strong cross-vein to the *v. mediastina,* and then continues on in a direct line to the tip of the wing. At a short distance from the origin this vein sends down a short abrupt branch, which meets a similar branch directed upwards from the *v. externo-media;* from the cross-vein thus formed, two veins take their rise; the upper I consider to belong to the *v. scapularis,* and to be properly a continuation of the short abrupt branch; it continues a short distance either parallel to the *v. scapularis* or adjacent to it (as in some Agrionina), and then branches; it generally branches twice before reaching the nodus, and once at or just beyond that point, with which it is connected by a continuation of the strong cross-vein before mentioned.[1] The *v. externo-media* runs quite directly to the margin, curving downwards more or less at the outer half, and running nearly parallel to the lowest branch of the *v. scapularis;* it sends upwards the short abrupt branch mentioned to meet that of the *v. scapularis,* which turns abruptly outwards at right angles again, sometimes joining the vein again a short distance on, sometimes continuing freely to the margin. The intricacies of the neuration are such that the *v. interno-media* can be traced definitely but a short distance, to a point below the cross-vein, uniting the *v. scapularis* and *externo-media;* here it sometimes forks, sometimes continues on single but contorted, and sometimes seems to stop altogether. The *v. analis* is frequently if not generally confluent with the preceding for a short distance, then diverges and forms the lower border of the wing. The *areæ marginalis, mediastina, scapularis* and *interno-media,* are traversed by numerous cross-veins; the *area externo-media* is free from them as far as the cross-vein; beyond this they are present; the spaces enclosed by the branches of the *v. scapularis,* and all the wing below the upper branch of the *v. externo-media,* are reticulated. That the space between what I have here considered as the lower branch of the *v. scapularis* and the upper branch of the *v. externo-media,* has cross-veins and no reticulations, except in a few cases close to the margin *(Æschnidæ)* is one reason for my conclusion concerning the meaning of the cross-vein and its branches.

Sialina.

The *v. mediastina* starts at considerable distance from the *v. marginalis,* approaching it

[1] In *Lestes,* however, it is somewhat different; it sends out a branch once before the nodus and once beyond.

gradually till it is in close proximity, when it terminates near the tip of the wing by striking the *v. scapularis;* this last runs close alongside of the *v. mediastina* and very nearly parallel to it, striking the *v. marginalis* at just about the tip of the wing. At about one quarter of the distance from its origin it sends forth a branch downwards and outwards, which having passed a distance about equal to that of the undivided parent stem, forks, the upper branch again forking, the upper branch of this fork again forking, and so on, the upper branches in their course gradually approaching nearer to the main stem, connected to it by a single cross-vein or two, and finally reaching the tip of the wing in close proximity; the various lower branches are connected together by a few scattered cross-veins, as are those of the rest of the wing. The *v. externo-media* starting and continuing in close proximity to the *v. scapularis,* diverges from it at about half the distance to the branch of the former; from here it runs parallel to the branch of the *v. scapularis* and not far from the middle of its whole course, and just below the divarication of the *v. scapularis,* forks, the upper fork sometimes forking again. The *v. interno-media* forks from its very origin, the upper fork turning sharply upwards against the *v. externo-media.* One examining these veins without great care would consider the former a branch of the latter, were it not that the branching does not occur in the lower wing of Chauliodes until a very little past the origin; beyond its collision with the *v. externo-media* the upper branch runs sub-parallel with the lower branch of that vein, and sends out branches from the under side more or less. The under branch, with a slight curve, runs directly to the margin, forking once a little before reaching it. The *v. analis* forks at its origin, the forks being connected close to the base by a cross-vein; each of the forks again divaricates, and their proximate forks are connected by a cross-vein.

Hemerobina.

This family includes a greater variety of forms than any other, even after we have excluded from it many of the lesser families with which they are erroneously associated (as I believe) by Hagen. To comprise the genera Ascalaphus, Nemoptera, Acanthaclisis, Polystoechotes, Chrysopa, Sisyra, and Drepanopteryx in one group and show a uniformity of character in the venation of the wings as great as they exhibit in other features, which shall also distinguish them from the other families, and especially from some of those included within it by Hagen, is certainly more difficult than the definition of many other of the families, including as it does the more aberrant forms of the sub-order. The lower wing of Polystoechotes is perhaps as fair an example as any of the family.

The *v. marginalis* is continuous and regular, except in Drepanopteryx, etc., where it is very much curved abruptly forward next the base. The *v. mediastina* is straight, and except where the *v. marginalis* is swollen, as in Drepanopteryx and Chrysopa, is parallel to the *v. marginalis,* terminating near the tip of the wing by striking either the *v. marginalis* (e. g. Chrysopa, Drepanopteryx,) or the *v. scapularis* (e. g. Acanthaclisis, Polystoechotes, Neuroptera, Ascalaphus, Sisyra). The *v. scapularis* runs parallel to the *v. mediastina* most of the way from the base to the tip, where it terminates, generally just at the tip. It sends down a branch, either quite near the base (Polystoechotes, Drepanopteryx, Sisyra), or at about one third the distance from the base (Ascalaphus, Acanthaclisis, Chrysopa), or even so far as the middle of the wing (Nemoptera), which strikes the border so as to include above it seldom less than half of the wing, and often (especially Polystoechotes) much more. From near the origin of this branch it sends forth another branch parallel to the main stem, which runs equidistant from it to the outer border, or reunites with the main stem, sending off continually branches parallel to the first-mentioned branch. These latter branches are either united by frequent or infrequent cross-bars, or they may fork to an indefinite extent, or only near the border, or the space between the first branch and its branchlet, parallel to the main nervure, may be filled with a net-work of veins. The main stem and the branch parallel to it may be united by few or many cross-veins. The *v. externo-media* may be either perfectly simple (Nemoptera, Acanthaclisis), or it may fork once from near where it leaves its close conjunction with the previous nervure, generally diverging narrowly, and have its forks continually united by cross-veins, while the spaces on either side are differently characterized, or in some other way show more or less distinction from the surrounding spaces, or it may so fork without such distinction (Drepanopteryx, Chrysopa, Polystoechotes), or it may fork farther from the base, and refork once or twice (Sisyra); at all events, it occupies quite an unimportant part, Chrysopa alone excepted. The *v. interno-media* extends generally some little distance from the base before forking, though sometimes it forks quite near to it, and generally occupies considerable space, in which the character of venation is similar in nearly every case to that seen in the space occupied by the *v. scapularis.* In Drepanopteryx, Nemoptera, Ascalaphus, and Acanthaclisis, they are especially prominent, while in Chrysopa the large extent of the *v. externo-media* seems to be balanced by the slight development of this vein, for it simply forks once, curving downwards and meeting the border. The branches proceed downwards toward the border mainly parallel to one another, and thrown off from the upper branch of the original fork, which itself runs in close proximity to the *v. externo-media.* The *v. analis* generally occupies but a small space, forking at least once, sometimes its forks uniting and from their union sending forth new forks. In one instance at least (Polystoechotes) it occupies a larger space, and forks indefinitely.

In that abnormal genus of Hemerobina, Nemoptera, where the hind wing is reduced to a long, ribbon-like appendage, the *v. externo-media* alone is wanting; all the rest are perfectly simple and parallel.

Coniopterygidæ.

In this family the venation is very simple. The *v. marginalis* (if it exists) is continuous. The *v. mediastina* is simple, parallel to *v. marginalis,* and extends to the tip of the wing. The *v. scapularis* forks near the middle of the basal half of the wing, the lower branch forking widely shortly before it reaches the lower angle, the upper continuing parallel to the *v. mediastina,* sending out a branch sub-parallel to the lower branch, which forks widely before reaching the border. The *v. externo-media* is simple, runs sub-parallel to the *v. scapularis,* and is united to it by the only cross-vein that exists in the wing, just anterior to the branching of the former. The *v. interno-media* forks at its origin, the forks continuing sub-parallel to the former. The *v. analis* exists only on the border, if at all.

Rhaphidiidæ.

The *v. marginalis* is continuous. The *v. mediastina* runs parallel to the former and strikes it in the apical half of the wing. The *v. scapularis* runs parallel also to the *v. marginalis,* and terminates at the tip of the wing. It sends off a widely diverging branch near the middle of the wing, which forks widely before it has passed half way to the margin, the upper fork running nearly parallel to the extension of the *v. scapularis*, and is united to it by several cross-veins, while the lower one keeps on nearly the original course. The two forks are reunited afterwards by a cross-vein which runs parallel to the border, and sends off several branches to it. The *v. externo-media*, running a short distance parallel to the last, soon diverges considerably from it and immediately forks, the lower fork reaching the border at the middle, or sometimes nearer the base. The upper fork, sometimes united to the *v. scapularis* by a cross-vein, soon forks again, its two forks continuing at about equal distances from each other, from the other fork, and from the branch of the *v. scapularis*. These three forks, half way from the original branching to the border, are reunited by cross-veins, which send forth borderwards other branches, which are sometimes simple, sometimes forked and sometimes united again by cross-veins, like the original branches which send forth others to the border. In a similar way are the outer upper ones united by cross-veins to the branches of the *v. scapularis*. The branches of this vein occupy more space and are generally more prominent than those of the *v. scapularis*. The *v. interno-media* forks close to its origin, is thereafter simple, or nearly so, but may have its forks united by an occasional cross-vein to one another, or to the veins on either side. The *v. analis* is unimportant and has but a single fork.

Mantispadæ.

The *v. marginalis* is continuous, curving upwards next the base. The *v. mediastina* runs sub-parallel to it, and terminates abruptly at the outer extremity of the pterostigma, on the apical half of the anterior margin, either by a cross-vein uniting the *v. marginalis* with the *v. scapularis*, or by abruptly bending upon the latter. The *v. scapularis* runs in a straight course to the apex of the wing, parallel and in close proximity to the *v. mediastina*, so long as that continues; it sends out two parallel branches near to one another at about the middle of the basal half of the wing, from the second of which springs a branch which runs parallel to the *v. scapularis* itself to the very tip of the wing, connected with it by an occasional cross-vein, and sending out equidistant branches parallel to one another and to the first branches mentioned. They fork once next the border, just before which they are united together by cross-veins or by recurrence. They are united in a similar way to the first branches of the *v. scapularis*, which latter are also united together by a cross-vein, which is a continuation of the parallel branch of the second branch but is placed at an angle to it. The *v. externo-media* forks widely at the very base, is almost immediately united again, from which union a short branch or cross-vein connects it with the *v. scapularis* anterior to its branching, while two others widely divergent at origin run sub-parallel to the branches of the *v. scapularis*, are again united not far from the margin by a cross-vein, from which springs another branch. The *v. interno-media* is simple, and is united by single cross-veins to the veins above and below. The *v. analis* forks but once.

Panorpina.

The *v. marginalis* is continuous. The *v. mediastina* is unimportant, parallel to it, and terminates by striking it at about two thirds the distance from its origin. The *v. scapularis* runs in contiguity with the former for a short distance, then diverging a little distance forks, the upper branch running parallel to the *v. mediastina*, and at about the same distance from it, as it is from the *v. marginalis*, till it terminates by striking the *v. marginalis* a little way beyond where the *v. mediastina* strikes it, never forking except sometimes near the tip.

The lower branch forks and reforks again several times. This vein, with the two previous, occupy just about one half of the wing. The *v. externo-media* can with difficulty be distinguished from the *v. scapularis* next the base, since it runs for a short distance in very close contiguity to it, after which it diverges and runs sub-parallel to the lowermost branches of the previous veins, forking about the middle of its course, each of the forks dividing once more. The *v. interno-media,* taking its origin at a distance from the *v. externo-media,* curves directly up into close proximity to that, then diverging runs nearly parallel to it, forking once at no great distance from the base (but in Bittacus at the base), thereafter remaining simple. The *v. analis,* except where it is atrophied, as in Bittacus, forks at the base. The upper branch, curving like the *v. interno-media* and running parallel to it, remains simple. The lower branch forks again immediately, the lower fork (forming the margin) dividing once more, but with these exceptions remaining simple. All the areas, and the spaces between the branches, but especially those beyond the middle of the wing, have conspicuous but very infrequent cross-veins. There are none in the *area externo-media* previous to the forking of the *v. externo-media.*

Phryganina.

The *v. marginalis* is continuous. The *v. mediastina* is straight and runs into the margin in the apical half of the wing. It is connected with the *v. marginalis* close to the base by a strong cross-vein. The *v. scapularis* branches very near the base. The upper branch simple, and running parallel to the *v. mediastina,* reaches the margin before the apex. The lower branch branches again before the middle of the wing, the branches connected half way to the outer border by a bent cross-vein, which sends out a branch parallel to and midway between these. The *v. externo-media* bends up towards the *v. scapularis,* then diverging from it forks not far from the origin, the branches united at half their distance to the border by a cross-vein, at which point they both fork, the upper fork of the upper branch again and again forking, each time approaching the lowermost branch of the *v. scapularis,* with which the last is joined by a cross-vein, which is continuous with the forks of this vein and the cross-vein of the *v. scapularis.* The *v. interno-media* is simple, and runs parallel to the lower branch of the *v. externo-media.* It terminates at the border or at a cross-vein which unites the lower branch of the *v. externo-media* with the border. The *v. analis* forks at the base, the upper branch running parallel to the *v. interno-media,* and united near the base to the other branches, one of which forms the internal margin and the other is short and unimportant.

Since form dependent on general structure is a characteristic of families, as Agassiz has well presented it, we might have properly anticipated what we now find from this review, viz.: that distinctions of a general nature in the neuration of the wings correspond with the family divisions; for it is upon the structure of the wings of insects that their form very much depends. Especially is this true in Neuroptera, where, as much as in any other group except Lepidoptera, the form is presented most obviously in the contour of the wings. No systematists, however, have used these characters in the Neuroptera to any extent so far as I am aware, except Burmeister, who has treated of them in a general way, but scarcely so as to allow of ready comparison between the families. Heer, also, in his work on the Fossil Insects of Œningen, has given in detail — and differing scarcely at all from what I have here presented — the mode of this venation in the Termitina. Besides these, I do not know that any authors have given any specific distinctions of families among Neuroptera drawn from these characteristics.[1]

To enable us more readily to inquire how the two fossil forms under discussion are related to living types, we will reproduce some of the more striking of these characters in epitome, and append a similar brief account of the venation of the wings in the fossils.

Termitina. Nearly the entire wing is taken up with the simple and parallel branches of the *v. externo-media*, the anal area being wanting.

Embidina. The *v. mediastina* terminates near the tip of the wing by impinging on the *v. scapularis*, which impinges in the same way on the *v. externo-media.* The *v. externo-media* occupies the middle half of the wing with a few straight, simple, or dichotomous branches, distantly united by straight cross-veins to one another and to the veins above and below; anal area considerable.

Psocina. V. mediastina insignificant. The *v. scapularis* occupies almost the entire wing and is the only forked vein in it. It sends out a branch not far from the base, from which arise most of the branches, which curve and refork in the freest manner (though the wing is less crowded with veins than ordinarily), united by only one or two cross-veins to one another. The anal area is more prominent than the costal.

Perlina. The *v. mediastina* is connected with the margin by numerous cross-veins, and terminates by impinging on the *v. scapularis.* The branches of this latter occupy the apex only of the wing. It sends out a slightly diverging branch, which remains simple about half its distance to the margin, then sends out simple branches from its under side, seldom united by cross-veins. The *v. externo-media* branches like the branch of the *v. scapularis,* at about the middle of the wing, is connected by a cross-vein to that branch at its divarication, while the branches of the *v. externo-media* are themselves connected here and there by cross-veins and recurrent nervules. The *v. interno-media* forks several times, the consecutive upper forks continually reforking, and connected by a cross-vein at last to the *v. externo-media* at its first divarication. By this continual connection of the principal veins, two large cells are formed in the middle of the wing, the upper open, the latter filled with cross-veins in one sex; the last three veins are of not far from equal importance.

Ephemerina. The first three veins are simple. The *v. externo-media* occupies the largest portion of the wing, though it forks and reforks but once or twice, the spaces being filled by many intercalary nervures proceeding from the outer border. The *v. interno-media* and *analis* are about equal in importance, and similar in character to the *v. externo-media,* though with fewer intercalary nervures. All the nervures are generally connected by frequent, straight cross-veins.

Odonata. The most peculiar in its venation of all the families. The *v. marginalis* extends only to the middle of the wing, the *v. mediastina* taking its place beyond. The *v. scapularis* and *externo-media* are connected close to the margin by a cross-vein, from which arise two veins which occupy the greater portion of the wing. The *areæ marginalis, mediastina, scapularis,* and *interno-media* are traversed by numerous cross-veins. The most of the rest of the wing is filled with minute reticulations.

Sialina. The *v. scapularis* sends forth a branch in the basal half of the wing, which strikes

[1] When this was written I had not seen Goldenberg's paper on the carboniferous Insects of Saarbrück, (Die fossilen Insectea der Kohlenformation von Saarbrücken, aus den Palæontographicis von Dunker und Meyer, Cassel 4°. 1854,) which must be excepted from this remark, for so far as was necessary for the object he had in view, he has given detailed comparisons of the venation in some of the families of Neuroptera. I hope to revert at some future time to the relation which the species of the genus Dictyoneura there described bear to the Sialina and other Neuroptera.

the border on the outer half, but near its origin sends out a branch which forks, its upper fork continually reforking (the lower remaining simple and connected irregularly by occasional cross-nervures) and remaining parallel to the main stem. The *v. externo-media* forks near the middle of its course, the upper fork sometimes reforking. The *v. interno-media* forks widely at its very base, the upper fork sending out branches from its under surface. It is of considerable importance, while the *v. analis* is of but slight significance.

Hemerobina. The *v. scapularis* is generally much as in Sialina, but forks generally near to the base, and the branches are straight instead of curved, seldom united by more than one or two cross-veins, and these generally very regularly disposed, frequently united close to the margin and immediately forking again. It occupies also almost the entire wing. The other veins are much as in Sialina, but quite insignificant.

Coniopterygidæ. The veins never reach the border, and are extremely simple, but they nevertheless do not seem to agree in character with those of any other family. The only branching vein is the *v. scapularis*, which occupies half the wing. It sends out from its under side distant from one another one or two branches which fork widely near the margin, sometimes connected by cross-veins. It is connected to the *v. externo-media* by a cross-vein.

Raphidiidæ. The *v. scapularis* does not branch until beyond the middle of the wing, then sends out a branch which forks and is reconnected, before reaching the border, by a cross-vein which sends out several branches to the border. This vein thus occupies the apex of the wing. The *v. externo-media* occupies the central and largest portion. It sends out branches connected by cross-veins which latter themselves send out towards the border offshoots, which are sometimes again reconnected.

Mantispadæ. The *v. mediastina* impinges on the *v. scapularis* in the outer half of the wing. The *v. scapularis* sends out near together, in the basal half of the wing, two branches, the outermost of which sends out a branch parallel to the main stem, which again emits branches towards the border parallel to and equidistant from one another. These unite next the border and then fork again as in Hemerobina. This vein occupies more than half of the wing. The *v. externo-media* is much as in Rhaphidiidæ, but branches nearer the base. The anal area is quite insignificant.

Panorpina. The *v. scapularis* forks near the middle of the wing, its lower branch repeatedly forking. It occupies about one third of the wing, taking in all the apical portion. The *v. externo-media* forks in a similar manner but altogether beyond the middle of its course. The branches of the veins in general are mainly confined to the outer half of the wing, and they are connected by distant, straight cross-veins.

Phryganina. The *v. scapularis* sends from its lower side close to the base a branch, which forks near the middle of the wing, the branches being connected together afterwards by a cross-vein, which continues on and connects the branches of the *v. externo-media.* From this continuous cross-vein a considerable number of branches are sent toward the apex. This is nearly or quite the only cross-vein in the wing.

Hemeristina.[1] The *v. scapularis* sends downwards a branch near the middle of the wing, which curves outwards so as to run nearly parallel to the main stem, and sends from its under surface several other branches, occupying about a third of the wing. The *v. externo-media* divides near the base, and its lower branch forks when about half way to the border

[1] These names *Hemeristina* and *Palæopterina* are proposed for the families of which Hemeristia and Miamia are believed to be respectively members; fuller details, as a basis for a better comparison, are given beyond.

of the wing. The *v. interno-media* branches many times but at a very slight angle; and the *v. analis* is not unimportant. All the veins and their branches are intimately united by very frequent, straight, strong cross-veins.

Palæopterina.[1] Both the *v. scapularis* and *externo-media* fork not far from their origin very narrowly, the lower fork of the former and the upper fork of the latter sometimes reforking near the margin. Together they occupy scarcely more room than the *v. interno-media,* which at a distance from the base sends downwards more diverging branches which are occasionally united to one another and to the previous vein by distant, straight, but oblique cross-veins, as are also the branches of the *v. scapularis* to one another. The *v. analis* occupies considerable space, sending out many narrowly diverging forked branches not dichotomizing.

Other important distinctions, drawn from or dependent upon the structure of the wings, will be found to be characteristic of the families of Neuroptera. They differ, for example, in the various positions assumed by the wings when in an attitude of repose.

In the *Termitina* the wings in their natural attitude when at rest are extended horizontally backwards, those of the opposite sides completely overlapping one another. There is no deflection of the costal area, and the anal area being absent there is no plication.

In the *Embidina,* according to Westwood, the wings are matted down upon the abdomen as in the orthopterous family Forficulariæ. From figures of them one would judge that there was no deflection of the costal area and no plication of the anal area, and that their position may be exactly as in Termitina.

In the *Psocina* they are extended backwards, sloping obliquely from one another like the roof of a house, their inner edges meeting loosely, without plication of the anal area of the hind wings; anal area of fore wings with a slight horizontal deflection; no deflection of the costal area.

In the *Perlina* they are extended horizontally backwards, completely overlapping one another; the anal area of hind wings plicated; the costal area of fore wings slightly deflected.

In the *Ephemerina* they are extended perpendicularly upwards, the surfaces of the opposite wings approximate, or sometimes separated by a slight, seldom a considerable, angle; no deflection of the costal area; no plication of the anal area.

In the *Odonata* they are extended either laterally and horizontally, or (Agrionina) upwards, and, by the structure of the thorax, backwards, the surfaces of the opposite wings approximate; the anal area not plicated; no deflection of the costal area.

In the *Sialina* they are extended backwards, incompletely overlapping one another, arched over the abdomen; a single plication or none in the anal area of hind wings; a slight deflection in the costal area of the fore wings.

In the *Hemerobina* they are extended backwards, steeply sloping obliquely from one another like the roof of a house, their inner edges in close contact throughout; no plication of the anal area; the costal area not deflected.[2]

The *Coniopterygidæ* and *Rhaphidiidæ* I have never seen alive, but they probably do not differ essentially from Hemerobina. Neither have I seen the *Mantispadæ,* but they are probably either as in Perlina, though without deflection or plication, or also without complete or any overlapping of the opposite pairs of wings as in Panorpina.

[1] See note on preceding page.

[2] But Savigny figures Nemoptera in an attitude like Ephemera.

In the *Panorpina* the wings are extended backwards horizontally or sloping slightly, the lower completely covered by the upper; the opposite pairs divaricate slightly, so as not to overlap one another at all, while the inner edges meet only along the basal half. The anal area is not plicated, nor the costal area deflected.

In the *Phryganina* they are extended backwards, steeply sloping from one another obliquely like a roof, at tip generally steeper, nearly vertical, and the opposite pairs appressed; the anal area of the fore wings deflected horizontally, those of the opposite pairs overlapping one another, the anal area of the hind wings plicated; the costal area not deflected.

In the *Hemeristina* the wings overlap one another horizontally very completely, even close to the base, probably arched over the abdomen, and probably with the sides protected near the base by the deflected costal area.

In the *Palæopterina* they overlap one another partially in a loose way horizontally over the abdomen, probably with no costal deflection, and in general as in the Termitina, though with not so complete an overlapping.

Some of the families of Neuroptera will also be found to differ in the position assumed by the wings of the pupa, as follows:—

Termitina. When developed more than as tubercles they are represented by Westwood as extended horizontally elongate over the abdomen, their inner edges touching at tip.

Psocina. Horizontally extended backwards in a level plane, not covering much of the abdomen, the posterior covered by the anterior.

Perlina. Same as in Psocina, but never covering any of the abdomen, the posterior being behind and not overlapped by the anterior.

Ephemerina. Curving backwards and upwards over the abdomen, the posterior covered by the anterior, the outer edges meeting along the median line.

Odonata. Projecting backwards in a level plane, somewhat deflected, the hinder edge downwards, those of either side parallel.

In the other families the wings are bent over, either curving over upon the breast or extended along the sides, the posterior partially or completely covered by the anterior, or with some modification of one or the other of these modes, so nearly the same as to make the distinctions valueless.

The families differ also from one another, but agree among themselves in the position of the head. In the Termitina, Embidina, Perlina, Sialina, and Raphidiidæ, the head is in the same horizontal plane with the body. In Psocina, Ephemerina, Odonata, Hemerobina,[1] Panorpina, Phryganina, Mantispadæ,[2] and Coniopterygidæ, it is in a plane vertical to that of the body. We do not know the position of the head in Hemeristina, but in Palæopterina it is horizontal.

From this review of the distinctions among the families we see that the *Hemeristina* are related to the Hemerobina and Sialina more than to any other, by the mode of branching of the *v. scapularis*; to the Ephemerina by the comparative importance of the *v. interno-media* and *analis*; to the Odonata by the character of the *v. marginalis* and *v. mediastina* in the basal half of the wing; to the Ephemerina again in the method of dispersion of the cross-veins;

[1] It may be noticed here that the larva of Myrmelion has the head horizontal.

[2] This is an additional reason why this should be separated as a family group from Raphidiidæ.

and to the Odonata in the strength and importance of the same; and once more to the Sialina in the form and manner of folding the wings; while it has distinctive characters, not only in the unusual combination of these peculiarities, but also in that the *v. marginalis, mediastina,* and the main stem of the *v. scapularis* are equidistant and parallel throughout, uniformly connected by straight cross-veins; in the peculiar curving of the principal branch of the *v. scapularis;* in the mode of branching of the *v. externo-media;* and in that the lower principal fork of the *v. interno-media* occupies more space with its branches, and is of more importance than the upper fork.

The *Palæopterina* show their relation to the Termitina in the character of the *v. mediastina* and the irregular cross-veins which run towards the margin; to the Termitina more than to any other, though not intimately in the mode of divarication of the branches of this same vein; to hardly any unless it be the Panorpina in the peculiarities of the *v. externo-media;* to the Hemerobina and still more to the Sialina in the structure (though in Palæopterina given with more precision and exaggeration) of the *v. interno-media;* to the Ephemerina in the mode of branching, and to the Sialina in the important development, of the *v. analis;* to the Rhaphidiidæ more than to any other, though but slightly, in the infrequency and manner of dispersion of the cross-veins, excepting the marginal ones; and to the Termitina in the obliquity of all the cross-veins apart from those on the margin, and generally in the manner of folding the wings in repose. In the importance of the *v. interno-media* and *analis,* occupying as they do fully half the wing, we have characters which of themselves would clearly separate this family from the others; we also find distinctions of sufficient significance in every vein of the wing except the *v. marginalis* and *mediastina.*

We have thus far treated only of the structure of the wings. In the Palæopterina, however, we have other portions of the body to examine in addition to these, though their structure is generally scarcely as distinct as that of the wings, being crushed and displaced.

The contour of the abdomen is best preserved, though least so at the terminal segment, the most important part. It is apparently depressed; the roundness of the lateral edges of the segments indicate a membranous rather than a corneous, or even coriaceous integument, broad at the base, slightly increasing in breadth towards the middle and then tapering considerably to the apex, the terminal segment apparently furnished with a pair of short, stout, conical, anal stylets, — in all this corresponding in general to what we find in some Sialina. The meso- and meta-thorax are somewhat indefinite in their outlines, but the inequalities of the upper surface and the direction of the principal wing-nervures, which afford us an indication of the point of attachment of the wing, together with the faint sutural marks, show that it was similar in character in this part of the body also to the structure we find in Corydalis, one of the Sialina. The prothorax is quite remarkable for its diminutive size, its width being only half that of the mesothorax. We find similar abrupt changes in the Rhaphidiidæ, but in the Palæopterina the prothorax is not, as there, lengthened anteriorly as a compensation, but is formed much as in Perlina, depressed, quadrangular, with a slight median carina, but its anterior edge produced in the middle to quite a prominent tooth. The anterior legs are wanting,[1] but both the other pairs are present in fragments, enough to show that they were of moderate length and strongly compressed,

[1] It will be seen in our description of the anterior legs and of the head, that we interpret these parts very differently from Professor Dana in his article in *Silliman's Journal.* The reasons for this we have given elsewhere. See *Amer. Journ. Science,* (2) XL: 268.

recalling vividly the Perlina. The outline of the head is partly very distinct and partly very indistinct, and is docked posteriorly by what indistinctly resembles the posterior two segments of the abdomen of another insect. It is depressed like the other parts of the body, and regularly ovoid in outline. The eyes are rather large, elongate, lateral. The other appendages of the head cannot be made out distinctly enough for any characterization, the only possible indication of antennæ being slight linear depressions in the stone. In those points which can be seen the head closely resembles the Perlina.

The only portion of the body besides the wings which is preserved with any distinctness in the Hemeristina is a fragment of a femur, which from its position on the stone may be assumed to belong to the anterior pair of legs. It is compressed, with a slightly swollen median ridge, as the femora of Palæopterina are. There is also an apparent fragment of a middle femur and tibia at their union, very indistinctly preserved. The most that can be said about it is that it seems to agree with the same parts in Palæopterina.

Now what is most interesting in this connection is, that the Neuroptera have been divided by Erichson, in this being followed by at least the German Entomologists, into two groups, called respectively the Neuroptera (comprising the families Sialina, Hemerobina, Coniopterygidæ, Mantispadæ, Rhaphidiidæ, Panorpina, and Phryganina), and the Pseudo-neuroptera (which include the Termitina, Embidina, Psocina, Perlina, Ephemerina, and Odonata), founded principally upon one very essential characteristic, — the complete or incomplete metamorphosis, *i. e.*, whether the pupa be inactive or active; in which latter case the rudimentary wings of the pupa are mere pads protruding horizontally or more or less deflected from the thoracic segments, and in the other are more developed and wing-shaped, encircling the sides and folded over upon the breast like Coleopterous pupæ; and in support of the naturalness of this division it is urged that in no other sub-order of Insects do we find existing simultaneously two so distinct forms of metamorphosis.[1]

We have already seen, by the comparison of the wings alone, that these two families of fossil Neuroptera borrowed from one and another of the other families characteristics of wing-structure, which show their close affinity to them. These families from which they were borrowed, will now be seen to belong, some to one and others to the other of these larger groups, proving that we have in our newly discovered families a Synthetic Neuropterous Type. And this is still more evident when we carry our comparisons into other parts of the body, as we may in the Palæopterina, where the meso- and meta-thorax and the abdomen remind us strongly of the Sialina, a Neuropteron, while the head and eyes, the prothorax and legs, quite as much bring the Perlina, a Pseudo-neuropteron, to our mind.

In the Hemeristina we have nothing of importance in this direction; but the femoral fragments agree so closely with the Palæopterina in its mimicry of Perlina as to lead us to suggest that in its other features it may also have followed somewhat the peculiarities of the Palæopterina in the equal distribution of its characteristics over a field embracing both the Neuroptera and Pseudo-neuroptera.

We shall have completed the task we have assumed when we have given in detail the

[1] I cannot, however, discover any one character common to the wing-structure of one of these two groups which is not found in the other as well, though the families of Pseudo-neuroptera are much more distinct from one another than in general are those of the Neuroptera among themselves; unless it be that the Phryganina are as widely separated from the more nearly related families as those of Pseudo-neuroptera are from one another.

characters of the families, genera, and species of the fossil insects referred to in the previous remarks.

Family PALÆOPTERINA Scudder.

Neuroptera of medium size. Body rather broad and flat; the head horizontal. Head oval, depressed; eyes rather large, elongate; thorax square and depressed; the prothorax and head much narrower than the rest of the body; legs compressed, not long; abdomen full, long, probably (like Corydalis) not corneous; the terminal segment probably with a pair of very short anal appendages.

Wings large and regularly rounded, very broad near the base, the two pairs nearly equal, extending beyond the abdomen, and when at rest both pairs reaching about the same point; with only a very few and slight cross-veins, except in the *area marginalis*, where they are numerous and irregular; when at rest, folded as in the Sialina.

The *v. mediastina* runs parallel to the *v. marginalis*, but not in close proximity to it. It terminates at about two thirds the distance to the apex by impinging on the *v. scapularis*, which runs parallel and quite near to the *v. mediastina*, reaching the margin just before the very extremity of the wing. The *v. scapularis* forks at about one fourth its distance from the base, the upper fork taking the direction mentioned and remaining simple, the lower diverging but little though with constant increment, forking at about three fourths the distance from the base, the forks reforking one or more times. The upper branch is connected by a few oblique cross-veins with the lower, which run outwards and downwards. The *v. externo-media* forks quite near the base, its branches but slightly divergent, sometimes forking again. The *v. interno-media* covers with its branches a wider space. It is at first about as divergent from the last as that is from the lower branch of the *v. scapularis*. It soon forks, the upper branch again forking twice, the forks remaining parallel but separated from one another at the start as widely as those of the previous vein at their termination. There are one or two cross-veins uniting these forks, and one or two uniting the upper branch to the lower branch of the previous vein, where it comes in close contiguity. Of the *v. analis* little can be said, except that it terminates in a large number of closely contiguous, parallel nervures, which arise from forks near the base, which seldom refork, the branches running parallel to the innermost branch of the *v. interno-media*. The *area marginalis* has a large number of irregular cross-veins curving outwards from the *v. mediastina* as in many Termitina. The wings are quite alike and weak. In the specimen they are in their natural attitude of repose, overlapping one another in a loose way upon the back, probably with no side support.

Genus MIAMIA Dana.

Head ovate; eyes oblong-ovate, situated on the sides in the middle, slightly approximate anteriorly, prominent above and below but not protruding laterally beyond the general contour of the head; prothorax as wide as the head, quadrangular, broadest anteriorly, the anterior border very much produced forwards into a median projection, both anterior and posterior angles prominent but rounded, the posterior border square; meso- and meta-thorax much broader than prothorax, with large, slightly elevated tubercles just within the base of the wings, as in Corydalis; middle and hind femora and tibiæ broad and not long, femora and tibiæ of equal length; abdomen large and plump, as in Corydalis, the basal joints not quite so large as the central, tapering regularly, though but little, from the middle to the tip; last joint considerably smaller than the penultimate, furnished apparently with a pair of very short, bluntly conical, anal appendages. The costal border of the wings is almost perfectly straight, till near the tip, at a point just before reaching the tip of the abdomen when the wings are at rest, where it begins to curve. The inner border begins to form an opposite curve at a corresponding point, and together they form a curve of perfect regularity with no angle whatever. The inner border is straight for some distance from this curve towards the base, the wing growing but slightly narrower till near the base, when it narrows suddenly, but (probably) with a regular curve.

The cross-veins connecting the branches of the *v. scapularis* are only two or three, running obliquely downwards and outwards from the upper to the lower branch at equal distances from one another, and the outer at a similar distance from the forking of the lower branch. The cross-veins, between the branches of the *v. interno-media*, run parallel to the inner margin between the extremities of those branches. The cross-veins are very slight, and in the case of those in the *area marginalis* are very irregular in direction and disposition, like the same space in the Termitina. In the other parts of the wing the two or three scattered ones in the places mentioned are regular and straight.

Miamia Bronsoni Dana.

Measurements: head, .10 in. broad; length of eye, .08 in.; length of prothorax, including front projection or tooth, .15 in.; breadth of meso-thorax, .25 in.; from the hinder edge of prothorax to the extremity of the abdomen, 1.12 in.; breadth of middle femora, .05 in.; length of hind femora (what is seen of them), .33 in.; breadth of same, .07 in.; length of hind tibiæ, .18 in.; breadth of same, .04 in.; expanse of fore wings, 2.16 in.; expanse of hind wings, 2 in.; extreme breadth of fore wing, .40 in.; length of the anal appendages, .05 in.

Head just twice as long as broad; prothorax of the same width as the head, the front border convex, produced considerably forward in the middle to a pointed and rather slender tooth, a very slightly impressed median carina extending the whole length of the prothorax, a scarcely perceptible linear impression crossing the hinder portion, starting from a little in front of the posterior angle and curving forward so much that the broad, straight, scarcely elevated ridge connecting its two extremities is equally distant from it and the hind border of prothorax; the sides of prothorax very slightly convex, the prothorax itself about five sixths as broad posteriorly as anteriorly. Femora (front legs wanting) broad, slightly swollen along the middle line, flat upon either side, the extremities docked, the angles slightly rounded. Tibiæ much narrower, with no median ridge except in the hind tibiæ, where it is slight in the middle. Wings in repose reaching the same point.

Family Hemeristina Scudder.

Neuroptera of large size. The prothorax is quadrangular, narrower than the meso- and meta-thorax, though not proportionally so much so as in the Palæopterina; the femora (probably the front pair) are as in the Palæopterina, but proportionally broader.

Wings large, long, about twice as broad beyond the middle as near the base, the costal border convex in its outer half, with numerous and prominent cross-veins, but no reticulations; when at rest, overlapping quite completely even close to the base, much as in the Perlina, and probably with the sides protected near the base by the deflected *areæ marginalis et scapularis.*

The *v. mediastina* and *v. scapularis* run nearly parallel to each other throughout their course. The *v. scapularis*, at about one third the distance from its origin to the apex, sends out a branch, which curves outwards and considerably downwards, again curving upwards, so that when about two thirds the distance from the base it is as far from the main stem as that is from the front margin; beyond this, it keeps apparently parallel with the main stem; at the deepest part of its curve it sends out a branch about as divergent from it as it was from its parent stem, which continues directly to the margin, and again, but a short distance further on, it sends forth another, which runs parallel to the former. The *v. externo-media* is found a short distance from the base in close contiguity with the *v. scapularis*, but forking as it separates from the former, the upper branch continues a short distance in close contiguity to it, and then passes unchanged to the border of the wing parallel to the lowermost branch of the *v. scapularis;* the lower branch runs in a direction parallel to the general course of the upper, and forks once a little more than half way to the border. The *v. interno-media* forks at its origin, both forks running very nearly parallel and in quite close contiguity to one another, and parallel to, but rather distant from, the lower branch of the *v. externo-media.* The upper fork again forks at a little distance from the origin, the forks keeping in close contiguity. The lower fork sends off from its lower side one or two slightly curving, rather divergent branches. Of the origin and branching of the *v. analis* little can be said; the branches are rather numerous and distant, and subparallel to the lower fork of the *v. interno-media* as continued in its first branch, and the area covered by it is large and well developed. All of these veins and branches are connected together by numerous cross-veins, which are quite prominent, equidistant, and equally distributed throughout the wing, much as in most Ephemerina.

The lower wing differs from the upper, so far as can be determined, in that the branch of the *v. scapularis* does not curve towards the main stem, and that there are other branches to the *v. scapularis* beyond the first, parallel to that. The veins below this were not easily distinguishable.

Genus Hemeristia Dana.

Prothorax equally wide throughout; the sides straight; the anterior and posterior borders slightly if at all convex; (fore?) femora as in Miamia, but proportionally broader, though with the same flat surface on each side of a slightly swollen middle ridge.

Wings of large size, probably extending considerably beyond the body, the costal border probably quite straight during the first part of its course, curving broadly towards the extremity, probably with the extremities rounded and without a pointed apex, and with a full anal area and angle. The second branchlet of the principal branch of the *v. scapularis* in the upper wing, previous to the origin of the third, is connected with the principal branch by sinuate cross-veins as frequent as the cross-veins in other parts of the wing.

Hemeristia occidentalis Dana.

The prothorax here is so indistinct and poorly defined as to be incapable of specific description, or of measurements. Mesothorax, .25 in. broad; the fragment of the (fore?) femur is .10 in. broad. The wings, too, being but partially preserved, it is impossible to give accurate measurements, save of parts within a wing. The probable expanse is 5.15 in.; the distance, when the wings are at rest, between the first branching of the *v. scapularis* on one wing and that on the other upper wing, is .50 in. The estimated breadth of each wing at its widest point, probably the same as that between the margins of the wings at rest at their widest point, is .85 in.; the distance between the origin of the principal branch of the *v. scapularis* of the upper wing and that of its second branch is .53 in.; the greatest width of the space between the *v. scapularis* and its principal branch in the upper wing is .11 in.; and the distance between the *v. scapularis* and the margin at this same point is .09 in. The figure answers better than description.

In this specimen the right upper wing overlaps the left upper wing, and the insect is seen from above.

Explanation of Plate VI.

Fig. 1. — The right upper wing of *Hemeristia occidentalis* restored, magnified 1½ diameters.

Fig. 2. — Restoration of *Miamia Bronsoni*, magnified 2 diameters.

The dotted lines in these two figures show the conjectural parts.

Fig. 3. — The four wings of *Hemeristia occidentalis* as seen in the fossil, magnified 1½ diameters.

Fig. 4. — The veins of the wings only of *Miamia Bronsoni*, as they appear in the fossil, magnified 2 diameters.

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VII. *On the Parallelism between the different stages of Life in the Individual and those in the entire Group of the Molluscous order Tetrabranchiata.* *By* Alpheus Hyatt.

Read February 21, 1866.

Heretofore all investigators of the morphological changes taking place in the individual during its life have directed their attention wholly to the examination of the younger stages, while the body is increasing in bulk, and the various organs are developing from an immature to a more or less matured condition.

The importance of continuing such researches throughout the entire life of the individual has not yet attracted the attention of naturalists, although, as I hope to show, the modifications which succeed the embryological stages, during the adult period and old age, or period of decline in the individual, are not less significant, or less worthy of the deepest study.

No one, with the exception of Alcide D'Orbigny, has yet attempted to describe systematically all the metamorphoses of an individual from its ovarian origin to its death, and even he has not detected the correlations which exist between these metamorphoses and the gradual changes which mark the course of life in the group, from its beginning in time to its extinction. D'Orbigny's observations were made upon the Ammonites, and having been engaged myself, for the past six years, in arranging the magnificent collections of Cephalopods belonging to the Museum of Comparative Zoölogy at Cambridge, Massachusetts, I have had ample means of testing the truth of his statements upon European specimens. The Museum collections are very richly furnished with Ammonites, nearly every species represented by a large number of individuals, and comprising, among others, the former cabinets of Prof. Bronn, L. de Koninck, M. Boucault, M. Duval, a large and choice selection purchased from Dr. A. Krantz of Bonn, and a suite of exchanges from the Museum of Stuttgardt. These having been placed temporarily in my charge, to be arranged in the show-cases designed for them, I availed myself of this favorable opportunity, while connected with the Museum in the capacity of a student, and since my graduation, to scrutinize closely the account given by D'Orbigny of the young, adult, and period of decline of the Ammonite.

These studies[1] finally led me to compare the characteristics of the period of decline the individual with the adult features of allied species in the hope of finding similar correlations to those so successfully worked out by Von Baer, Professor Louis Agassiz, and others, between the development of the young and the permanent states of simpler organizations. That correlations of a definable nature exist, I have no longer any doubt; and after completing the partial comparisons hitherto made only between the young of the Ammonites and the shells preceding them in time, I hope to show that the life of the individual, so far as the shell and its internal structure indicate what its metamorphoses were, displays during its rise and decline, phenomena correlative with the rise and decline of the collective life of the group to which it immediately belongs.

D'Orbigny divides the life of the individual into five periods, distinguishable from each

[1] I have also undertaken, at the suggestion of Professor Agassiz, a Catalogue of the Ammonites, the first part of which is now ready for the press and only waiting his return from Brazil to be published; in this will be found the names of every new species that may be mentioned farther on.

other by the external characteristics of the shell:[1] namely, the first period, or "période embryonnaire," during which it is smooth and the abdomen[2] round; the second period, or "première période d'accroissement," which is marked by the advent of the tubercles, or ribs and keel, if there are to be any upon the adult shell; the third period, or "dernière période d'accroissement," during which the tubercles, or ribs and the keel, are fully developed, and the whorl takes on its adult configuration; the fourth period, or "première période de dégénérescence," during which the ribs or tubercles begin to separate more widely and become depressed; and the fifth period, or "deuxième période de dégénérescence," when all these ornaments are obsolete, and the exterior is smooth again as in the young.

The recapitulation in which he sums up the results of this remarkably original and unique series of observations is equally truthful and instructive. The following paragraph conveys the sense of the original, though the piquancy and force of the French is lost in the translation.

"These modifications are not due to chance, but to decided and regularly occurring periodical metamorphoses, which affect the larger number of the Ammonites, and which invariably operate in a regular order of succession. In fact, each one, although smooth in the youngest period, covers itself at a later time in the course of growth with tubercles around the umbilicus, afterwards with ribs, striations, or tubercles, upon the back (abdomen). It is then in the adult stage. Having arrived at the maximum of external complication, all these ornaments begin to show signs of alteration; it degenerates; its striations and dorsal (abdominal) ribs first disappear; then follow its lateral ribs or tubercles, and in old age it becomes fully as simple externally as it was during the embryonic period."

The accomplished author of the "Paléontologie Française," however, did not extend his researches to the internal organization beyond a merely casual notice of the simplicity of the lobes of the septa in the young; and, also, positively denied that these parts were affected by old age: "ne montrent qu' une complication toujours croissante et jamais de dégénérescence."[3]

Robert Owen, the great comparative anatomist, states that the young Ammonite has an embryonic stage of development, when its septa resemble a Ceratite,[4] but besides this, three more periods can be traced, — one in the young, one in the adult of all shells, and the other in the old age of a limited number of forms, making altogether four periods of septal growth.

The first period, corresponding with D'Orbigny's "période embryonnaire" of the external characteristics, has simple septa curved like those of *Goniatites Marcellensis*, or any of the Nautilini, and the siphon occupies an abdominal position, giving rise to an exceedingly shallow abdominal lobe. The second, the equivalent, with reference to the more complicated adult septa, of the second period of D'Orbigny in the development of the ex-

[1] Alcide D'Orbigny, *Pal. Française, Terr. Crét. Ceph.*, p. 377.

[2] D'Orbigny calls the outer part of the whorl the back, but in common with Pictet and Agassiz I would regard it as the abdomen.

[3] D'Orbigny, *Op. cit.* p. 396, 2°. On the preceding page, however, he partially contradicts this assertion by doubtfully referring certain changes of the septa either to sickness at the approach of death, or to old age, "Ce cas a lieu généralement dans les dernières cloisons qu' une Ammonite a formées avant sa mort, et parait être la suite d'une maladie ou de la vieillesse."

[4] Robert Owen. Paleontology, p. 103, 2d ed., 1861. The same authority (p. 99) also states, that "the sutures of an Ammonite are at first very slightly lobed, and become progressively more complex; so that specimens of the same species have been referred to three genera — Goniatites, Ceratites, and Ammonites, according to their age."

ternal ornaments, and of the Ceratitic period of Owen, has a deeper abdominal lobe, and the lateral portions of the septa bent into a number of pectinated, club-shaped lobes like those of *Ceratites nodosus*. This period is not invariably coincident with the first appearance of the tubercles; on the contrary, it often precedes them, occurring while the shell is still smooth, as in *Amm. Kridion* D'Orb., or *Amm. Beechei* Sow. It is rare, however, to find a shell in which the septa have attained to any considerable degree of complication before the beginning of the tubercular period. The third period is always partly coincident with the third period of the external ornaments. It includes the septa from the time they acquire their Ammonitic lobes until they begin to degenerate in old age, and usually accompanies the ornaments through the entire course of their adult complication. The fourth period is not always distinguishable; thus *Amm. heterophyllus, Amm. primordialis,* and the like, which habitually increase the radii of the spiral throughout life, present no very decided marks of septal degradation in the oldest parts of their shells. In those species, however, such as the Planulati and Macrocephali, in which the radii of the spiral in the old decrease, the size of the whorl also diminishes, consequently crowding the lobes together, narrowing the breadth of the cells and preventing the formation of new auxiliary lobes. In fact, the complexity and number of the lobes seem to depend wholly upon the unceasing expansion of the whorls. There is then more room for them, and they either broaden, or an additional number of auxiliary lobes are added, as in the old of any of the more involute species of the Arietes, Falciferi, Dentati, Fimbriati, or Heterophylli. When the recession of the spiral takes place among the keeled Ammonites it may occasion the atrophy of the keel and an approximation to the aspect of species having rounded abdomens, as in the example given by D'Orbigny and Pictet of *Amm. varicosus* Sow., which loses its keel in the old, and resembles some of the Capricorni (*Amm. planicosta*).[1] There is, therefore, a general agreement between the mutations of the septa and form of the whorl, with those of the superficial characteristics of the shell; sufficient, indeed, to show that all the parts are more or less interdependent, and have at least four distinct periods during which they are mutually modified, viz: two periods of development, one adult period, and one old age period. The fourth period of the septa, when it does occur, is necessarily coincident with the fourth and fifth periods of the external ornaments, since the last two invariably accompany the diminution in bulk of the old whorl, and the degradation of the septa during the fourth period also depends upon the contraction of the interior caused by this diminution.

The correlations of these periodical revolutions in the life of the individual with those displayed on a greater scale in the life of the entire order of Tetrabranchiates in time, are wonderfully harmonious and precise. They open a vista through which the individual may be viewed in a new and unexpected light; standing side by side with its own series of forms, it seems to embody the same biological law; not only rising and declining within the narrow limits of its separate existence as they do in their totality, but varying the characteristics of its different periods reciprocally with the more extensive changes of the entire series.

The general agreement of the life of the individual and the life of the group are evident and need no extended explanations; but for the purpose of entering more minutely into these comparisons, it will be necessary to give a summary of the principal points in the history of the order. The Tetrabranchiates are specially suitable for an inquiry like

[1] D'Orbigny, *Op. cit.* p. 295, and Pictet, *Traité de Paléont.*, II. p. 676.

the present. With the exception of two species now living, they are extinct, and the possibilities of their structural combinations were exhausted even before the extinction of the Cretaceous fauna. The shells, also, are not simple, like those of others of their own subkingdom, but are provided with a series of partitions or septa, which afford additional means of verifying the observations made upon their superficial characteristics. The objections usually urged against the accuracy of investigations founded solely upon the shell, cannot, therefore, have the same weight, when they are supported, as in the Tetrabranchiates, by the evidence of internal structures. In some respects shells are the most satisfactory of all animal remains. While the bones of the extinct Vertebrata, the casings of the Echini and Crustacea, and other fossils, give us in each specimen but one period or stage of growth, shells embody in nearly every well-preserved example a history of the individual from its earliest period to its death. The shell, indeed, is but a single organ, but then it retains the impression of the contour and many of the minor peculiarities of the softer parts, and when we have another set of internal hard partitions of acknowledged importance, there is but slight danger of overrating the value of their evidence.

The Nautiloids commence in the Silurian with aberrant genera, such as Orthoceras, Phragmoceras, Gyroceras, Lituites and others, and these gradually die out until they are no longer to be found in the Jurassic. The normal discoidal Nautili begin in the Upper Silurian with two species[1] and gradually gain in numbers, amounting in the Carboniferous to upwards of thirty-eight species, and then decrease until but two species survive in the seas of the present day. The greatest variety in the form of the adult whorls and the most complicated ornamentation is exhibited at this epoch, when the number of the species and the vital energies of the series are at their maximum. There are globular, keeled, channelled, flattened, smooth and tuberculated species, — all those essential differences of the adult whorl which vary its form but one, the complete involution of the spiral. Subsequently these ornamented and keeled species gradually disappear before the striated and ribbed Nautili of the Jura and Cretaceous, and the latter before the smooth Nautili, which have been slowly gaining in number and importance ever since their first appearance in the Silurian. There are only six of these in the Tertiary, whereas there are about eleven smooth species, according to Giebel, in the Cretaceous.[2] Thus while their predominance in the Tertiary is significant of the extinction of the more highly ornamented species of the Nautili, their falling off in number shows the whole of the Nautiloids to be approaching their dissolution.

The same laws, however, do not obtain with regard to the greater or less involution of the shell and the complication of the septa. The Nautili of the Carboniferous and preceding geological formations are not involute, but those of the Jura and succeeding formations have the umbilicus more or less covered by the enveloping whorls; the septa are reciprocally progressive, and attain their highest complication in the angular lobes of *Nautilus ziczac* of the Tertiary. Thus during the decline of the Nautiloids, both in the number and in the variety of the form and ornamentation of their whorls, the very species that indicate this decline are becoming more complicated in respect to the involution of the whorls and the formation of the lateral lobes.

This sustained progression corresponds precisely with what may be observed among the individuals of the series. From the earliest period they perpetually lengthen the radii of

[1] Mentioned by M. Barrande in "Étage E" of Bohemia. *Quart. Journ. Geol. Soc., London*, Vol. X. (Translation).

[2] Giebel, *Fauna der Vorwelt, Ceph.* iii. 1852.

the spiral, increasing the bulk of the whorls and deepening the flexures of the septa. Age, indeed, seems to produce no greater impression upon these features in the individual than it does in the whole group. There is every reason for supposing, also, that in its other characteristics the shell agrees equally well with the decline in the whole group of the ornamented species and their replacement by smooth shells.

If the growth of the ornamented carboniferous shells agrees in any manner with their representatives, the ornamented and keeled Ammonites, the adult ornaments either entirely vanish or become partially obsolete in the old. We should then have in any one individual three periods answering to the three periods in the general life of the series: the youngest period with its bent, non-enveloping, smooth tube, and simple septa resembling a Phragmoceras, or a Cyrtoceras among the aberrant genera; the adult period with its profusion of ornaments especially belonging to the epoch of its occurrence and the returning smoothness foreshadowing the smooth shells of the last days of the entire series.

I have not yet had an opportunity of examining any specimens of the ornamented Nautili which betrayed evidences of senile degeneration; but this is not surprising, since among hundreds of Ammonites it is often impossible to pick out one specimen which presents a complete history of its own life.

The Ammonoids are the opponents of the Nautiloids, expressing in every step of their serial arrangement opposition to the latter, reproducing the same forms, but in such succession, that they are removed from their prototypes among the Nautiloids to the greatest possible degree both of time and organization. For this reason, and because the word has been used to designate similar phenomena by others, I shall call this general repetition of form morphological polarity, whether it be in the young and old periods of the individual or of the group.

The series under consideration begins in the Devonian with the normal discoidal shells[1] of the Clymeniæ, and mounting step by step in the complication of the septa, the multiplicity of the forms and the number of species, reaches its culmination in the Jurassic and dies out with the Cretaceous.

The number of species in the Jurassic, according to D'Orbigny, are in the aggregate about two hundred and twenty-two, whereas those of the Cretaceous are but one hundred and forty-four, making an excess in the Jura of seventy-eight species.[2] The researches of the same indefatigable paleontologist have demonstrated that the Ammonites differ from the Nautili in the suddenness with which they disappear, having, according to his "Prodrome de Paléontologie," upwards of forty-two species in their last geological horizon, the "Sénonien." The aberrant genera, on the contrary, first announce themselves with two species of straight shells of the genus Bactrites in the Devonian, and progressing very slowly do not arrive at the maximum number of species until the close of their career in the "Sénonien." Out of eighty-six in the Cretaceous, about fifty, or more than one half, are confined to this formation, and exceed the normal forms only by some eight species. Many of these aberrant genera are precise repetitions of the aberrant Nautiloids, which in the Silurian were, also, numerically superior to the normal Nautili. The Baculite, for instance, is a straight cone like the Orthoceratite; the Turrilite is a turbinated form

[1] There can be but little doubt of the affinity of the Clymeniæ with the Ammonoids, since the discovery of the Clymenia pseudogoniatites (Guido Sandberger, Beobacht. über d. Clym. Wiesbaden, 1853) This species, an undoubted Clymenian, has well-defined abdominal and lateral lobes, which are undeniable Ammonitic characteristics.

[2] D'Orbigny, *Prod. de Paléontologie*, Vol. III., 1850.

similar to Trochoceras; the Crioceras an open coil answering to Lituites; the Toxoceras a curved tube like Cyrtoceras, and so on. Most of these are exclusively Cretaceous and, as will be shown presently, are at the head of the Ammonitic series. Thus those approximating to the normal, discoidal Nautili in form are next to them in time, and those approximating to the beginning aberrant Nautiloid are the farthest removed. The Ammonoids, therefore, are in every respect polar to the Nautiloids, and entirely revolutionize the succession of the latter. This is equally well exemplified in the morphological sequence of their structure. The Orthoceratite, on account of its simple concave septa, straight cone, and priority of geological position, may be considered as the elementary form. Between it and the involute discoidal Nautili, we find the Cyrtoceras and Phragmoceras somewhat more bent, and the septa with very shallow lateral lobes; the Gyroceras with a very loosely coiled shell, and the lateral lobes deeper; Lituites closely coiled with two shallow lateral lobes; and lastly, the discoidal Nautili leading to the involute *Nautilus ziczac*, and its angular lateral lobes and rounded cells. Among the Ammonoids, there are the Clymeniæ simulating in the lowest species, such as *Clymenia lævigata*, the open umbilicus, almost dorsal siphon and simple lateral flexures of the Trocholites or Lituites, and in the highest, *Clymenia pseudogoniatites*, having perfect angular lateral and abdominal lobes. Next the Goniatites and Ceratites, with their more involute forms and numerous lobes and cells, and the keeled Ammonites with a greater variety of forms and foliated lobes, and then the group of Ammonites with round abdomens which precede the tubular aberrant genera and connect them with the discoidal Ammonites. Lastly, the aberrant genera themselves, which are successively more and more open from the Scaphites, as will be shown farther on, to the perfectly straight Baculites. This of course is not strictly their connection, because no directly traceable linear series exists, but only the general resolution of the elements of form as determined by the special affinities of the septa. Morphologically, therefore, and with regard to the general sequence in time and structure, the aberrant Nautiloids are to the discoidal Nautili as uncoiled cones to involute cones, and the discoidal Ammonites to the aberrant Ammonoids as involute cones to uncoiled cones. In other words, if we wish to look at the order as a whole we may consider the straight Orthoceratite as coiling upon itself and producing the discoidal shells, and these uncoiling to generate its structurally antithetical but polar form, the straight Baculite.

The senile period of the individual may be contrasted with the young, as the Ammonoids were with the Nautiloids, and its polarity to the young expressed in nearly the same phraseology which was used to describe the morphological inversion of the two series by simply substituting the terms "old age" for "Ammonoids," "rising period" for "Nautiloids," and "characteristics" for "forms."

Thus it may be said that the old age of the individual is the opponent of the rising period, expressing in every step opposition to the latter and reproducing the same characteristics, but in such succession that they are removed from their prototypical characteristics to the greatest possible degree both of time and organization. Thus; the external ornaments, as previously stated, in dying out pass through a series of changes which are inversely the same as those by which they came into being, and the periods most alike are the two smooth ones situated at the extremes of individual life. The polar forms are morphologically unrolled Ammonites, and in dying out pass through a series of forms which are inversely the same as those by which the Nautili came into being; and the forms most alike are the two straight cones, the Orthoceratite and the Baculite, situated at the extremes of the collective life of the order. The forms of the order and the characteristics of the isolated shell both undergo, after their vital powers are expended, a reversion which approximates the aspect of the exterior of the shell and the forms of the order to their original simplicity.

Farther; during the rising period of individual growth the septa are constantly complicating to correspond with the equally constant increase of the radii of the whorls, but in old age, as previously stated, the septa deteriorate because the whorl becomes more tubular. The order also during its rising period has constantly complicating septa, and in its decline, when the whorls become more tubular and less involute among the aberrant genera, these parts present marks of degradation and have fewer lobes than the involute shells, not above six in all, — which is the number usually found in the young Ammonite at the Ceratitic period.

The old septa of the shell of the individual retain much of the adult complication, parting only with those characteristics which are immediately influenced by the degradational changes in the breadth of the whorl. The lobes and cells may be crowded together or otherwise modified, but they still hold, even in extreme old age, to the Ammonitic foliations, and never become smooth again as in the young, however much the whorl may be rounded or otherwise brought to resemble the young. In the order, also, though the polar forms so closely copy their prototypes and the septa have fewer lobes to correspond with the degraded character of the whorl, yet they never lose the Ammonitic foliations, or repeat the smooth septa of the prototypical Nautiloids.

Thus the polarities of the individual are exhibited in the same manner as those of the whole order with reference both to time and mode of occurrence, agreeing even in the negative features last described, in the extent to which the septa may be changed by the degradation in form of the old whorl and the decadence of the entire group. These polarities, however, are not so complete as some which may be made by contrasting the life of the individual as a whole with that of the order, and thus bringing into view not only the agreement of polarities but the agreement of the intermediate adult period.

The Tetrabranchiata, as regards their progress in time, have four periods of greatest expansion: the first, in the Silurian; the second, in the Carboniferous; the third, in the Jurassic; and the fourth, in the Cretaceous. These are the epoch of geological history, when the four separate groups had their maxima of development, as previously estimated by the number of species, the multiplicity of their forms, and their profuse ornamentation. They show that the groups, although parallel with each other in the general phenomena of life, — namely, having a beginning in time, from which they augment in complication and in numbers and then die out, — nevertheless do not perform their cycles together, but each by itself, and arrive at their maxima regularly in the order of their zoölogical rank. The aberrant Nautiloids have, according to D'Orbigny,[1] about one hundred and fourteen species in the Silurian, decline to (about) sixty-four in the Carboniferous, and to (about) fourteen in the succeeding strata, and are absent, as previously remarked, in the Jura. They therefore predominate over the Nautili, which amount to thirty-eight species in the Carboniferous, and only (about) eight species in the strata intervening between that and the Jura, until they are replaced by the Nautili in the last named formation.

The Ammonites in the Jura, as previously stated, run up to more than two hundred

[1] D'Orbigny, *Prod. de Paléontologie*, Vol. I., 1850.

species and, therefore, vastly surpass their predecessors the discoidal Nautili, which are represented by only a few more than twenty species in the same formation. The aberrant Ammonoids differ from their prototypes in one respect: they do not outnumber the discoidal shells in the Cretaceous, as the aberrant Nautiloids of the Silurian did the normal forms of their special group, but the normal Ammonites have much the largest number, being as one hundred and forty-four to eighty-six. In the last horizon of the Cretaceous, it is true that the polar forms exceed them, as has been shown, by about eight species, but this is only sufficient to demonstrate that the latter are gaining, and does not afford margin enough for the assumption that their superiority is comparable with the vast predominance of the aberrant Nautiloids in the Silurian. Although the polarity is here less accurate than in other respects, the succession of the four epochs resembles the succession of the four periods of the individual both in number and their general structural peculiarities.

The first epoch of the order is especially the era of rounded, and, in the majority of the species, unornamented shells with simple septa; the second is the era of ornamentation, and the septa are steadily complicating; in the third the complication of the septa, the ornamentation, and the number of species, about twice that of any other epoch, all combine to make it the zenith of development in the order; the fourth is distinguishable from all the preceding as the era of retrogression in the form and partially in the septa.

The four periods of the individual are similarly arranged and have comparable characteristics. As has been previously stated, the first is smooth and rounded with simple septa; the second tuberculated and the septa more complicated; the third was the only one in which the septa, form, and ornamentation simultaneously attained the climax of individual complication; the fourth, when amounting to anything more important than the loss of a few ornaments, was marked by the retrogression of the whorl to a more tubular aspect, and by the partial degradation of the septa.

This exhausts the correlations between the individual as a unit and the whole order. There yet remain, however, those which may be traced in the proportions of the embryonic, adult, and old age features of the shell; by their aid we shall be able to perceive the extraordinary correspondence of the life of the individual with its position in the structural scale.

The adult period of the individual is evidently that which differs most from all the rest, since these, as has been shown, are inversely repeated on either side, and it alone remains non-conformable to any other.

Examining the order, it is not difficult to perceive that at the epoch of the Jura, corresponding to the adult period of the individual, the Ammonites depart to the utmost extent from their polar types the Orthoceratite and the Baculite, since, as we have also seen, this epoch is remarkable for the combination of all the elements of complication and their simultaneous arrival at the maximum of vital intensity.

It is also most remarkable, that the growth of the individual itself is strictly conformable with this law, being more homogeneous or embryonic in the Orthoceratite, heterogeneous or continuing to increase the diversity of the adult from its own young throughout life at the era of greatest vital intensity among the Ammonites, and more homogeneous or embryonic again in the Baculite. An adult Orthoceras has precisely the same concave septa and round whorl as the young; the septa of an Ammonite may vary among the keeled group from four rounded to eighteen foliated lobes, and the form from an open coil to a completely covered umbilicus (*Amm. discoides* Ziet., *Amm. discus* Sow.), or among the smooth round-backed group from four to twenty-two (*Amm. Calypso* D'Orb.); the septa of a Baculite, however, retain the embryonic number of four or six lobes and have precisely the same form in the adult and in the young.

This law proves that there is a direct connection between the position of a shell in the completed cycle of the life of this order and its own development. Those shells occupying the extremes of the cycle, the polar forms, being more embryonic than the intermediate forms, although in regard to geological sequence and structural position one of the extremes must be of a higher zoölogical rank.[1]

There is, however, another and more striking correlation between the Ammonites of the Jurassic era and the adult period of individual growth. All the shells of earlier eras among Ammonoids, such as those of the Clymeniæ, Goniatites, and Ceratites, are deficient in senile characteristics. The radii of their whorls do not diminish in old age, nor do their septa or ornamentation show any signs of degradation; each successive species adds something to the increment of complication, and there are no visible traces of a failing vitality, so far as I know, either in the individual or in the group to which it belongs. But in the same manner that the individual begins to show signs of decay during the adult period do the Ammonoids begin to produce individuals and species with well-marked senile characteristics at the moment when they reach their maximum of development in the Jura. Doubtless the softer parts were affected by the decline of the vital powers of the individual among the earlier series, above mentioned, but the changes were not such as to visibly affect the shell or the septa.

Among the Nautiloids, also, this law appears to hold, since, as previously described, they maintain the progressive complication of their septa throughout the series, and if there are any signs of senile degradation they must be found among the ornamented species of the Carboniferous, when the group reaches its fullest expansion. Within itself this series may, as I have inferred, correspond with the changes of the different periods in an ornamented individual of the Carboniferous; but with regard to the order of Tetrabranchiates it is eminently a "progressive series." It forms the organic base of the order, as the Clymeniæ form the organic base of the Ammonoids; but while it completes the cycle of its life they do not, but are cut off after existing for a limited time in the midst of their growth. The Nautiloids, in fact, are dying a natural death of decay; whereas the Clymeniæ, Goniatites, and Ceratites were for the most part abruptly destroyed at the end of the Devonian, Carboniferous, and Triassic epochs. The concentration, also, of the whole progress of the Nautiloids within the boundaries of one small group, the Clymeniæ, as will be seen presently, confirms their progressive nature and shows them, notwithstanding their wide-spread distribution, to be but little more than an equivalent of the latter.

The first septum of *Nautilus Pompilius*, and also of *Nautilus lineatus* from the Inferior Oölite, and of *Nautilus bohemicus* Barrande, according to D'Orbigny's figure, has an abdominal cell, and the lateral portions slightly sinuous, and the siphonal aperture even at this early age is central. The striations are broader externally than internally, indicating from the apex the tendency towards the spiriform mode of growth.

The presence of the siphon shows that the young does not repeat the siphonless adult

[1] That this "higher zoölogical rank" also implies relatively a higher organization, although, as here stated, the adult may be quite embryonic and differ but little in the characteristics of the shell from its own young, may be seen by referring to the last page of this article.

[2] D'Orbigny, *Op. cit. Terr. Jurass. Ceph.*, pl. 31, p. 156; Barrande, *Op. cit.*

condition of some of the lower genera, such as Endoceras. There is, however, a faint reference, perhaps, to such species as *Tretoceras bisiphonatum*, caused by a minute dorsal lobe in the young of *N. Pompilius*, which from its position and general appearance might be homologized with the dorsal chambers of that species.[1] The plainly convex septa, equable striations, and straight mode of growth of the Orthoceras is also omitted, the young shell being wholly devoid of resemblance to these simplest forms. It is presumable that in their earlier periods the ova have characteristics in common; but certainly after these egg phases are past, if there are resemblances between the embryonic Nautilus and the adult Endoceras or Orthoceras, they are too transient to make any impression either upon the mode of growth, the septa, or the curvature of the shell.

Entering upon the Ammonoid series, the first member of it, the Clymeniæ, confined to a single geological epoch, the Devonian, centres within the boundaries of one small series of shells like *Clymenia lævigata*, that are separable from Trocholites only through their external outline, which is flatter or more definitely discoidal than the spiral of the latter, and the *Clymenia pseudogoniatites*, which we ascertained to be a true Ammonoid.[2] The range of the complication is greater, so far as the septa are concerned, than that traversed by the Nautiloids in almost the whole of geological time from the Silurian to the Tertiary. A still more decided concentration is exhibited in the last named species, every individual of which, according to Guido Sandberger's figures, begins life with the simple septa of a *Clymenia lævigata* and crowds all the essential steps of the entire advance into its younger periods. Whether the Clymeniæ are true Ammonoids or not is of no material consequence; certainly, in one division, and, finally, in the young of one individual of that division, and in a proportionately shorter time, they bring together by successive concentrations the results of the progress of the Nautilian septa, and proceed in the adult to make a yet greater advance in another direction towards the more highly constituted Ammonoids.

The Goniatites do not repeat in their young the position of the siphon in the Clymeniæ, although the septa may be quite as simple as they are in *Clymenia lævigata*. It is possible that the siphon may alter its place in the young of such simply septate species as *Goniatites marcellensis* Van., but this is exceedingly doubtful, since in species as simple as *Goniatites discoideus* Hall, the siphon is ventral at an early period of growth. The range of complication is greater than among the Clymeniæ, being from *Goniatites marcellensis* with two shallow lateral lobes to *Goniatites ceratitoides*, which closely approaches the Ceratites in the shape and number of its club-shaped lobes. The development of the septa accords with the growth of the same parts in the Clymeniæ, since among the lower species it takes a longer period to bring the lobes and cells to their full development than in the higher. Thus in *Goniatites marcellensis* the septa have about the same embryological curves throughout; in *G. lamed* Sand., a more complicated species with two angular lateral and one large divided ventral lobe, they take on the adult aspect during the second or third whorl, having passed through a stage equivalent to the adult period of *G. marcellensis* during the first whorl; and in *G. crenistria* Phill., a still more advanced species, the changes are introduced even more

[1] This homology seems to confirm Mr. Salter's opinion, that the dorsal (his ventral) chamber is wholly independent of the siphon. (Salter on Tretoceras. *Journ. Geol. Society*, London, 1858.)

[2] I connect *Clymenia lævigata*, which, together with its allied species, has been placed by several authors among the Nautiloids, with *C. pseudogoniatites*, through such species as *C. binodosa*, *sublævis*, or *costellata*, all of Munster, which have the angulated Clymenian septa in the adult, but are like the adult *C. lævigata* in the young, both in the external striations, form of the whorl, and curvature of the septa.

rapidly. The development varies, also, among the Ammonites, according to the adult complication of the septa, the siphon being constantly ventral. As has been described, there is a goniatitic and ceratitic stage, and these are both passed through almost invariably in the first whorl, and in some highly complicated species, such as *Amm. discoides* Ziet., or *Amm. Beechei* Sow., the septa are deeply foliated in the young.

In both the Goniatites and the Ammonites the central position of the siphon, so conspicuous among the Nautiloids and Clymeniæ, is passed over, and left out in the course of growth, and the development of the septa accelerated in proportion to the position of the shell. Thus among the Clymeniæ, as a rule, it is slower than among Goniatites, and slower in the latter than in the Ammonites; although in each division there are, also, differences in the rapidity with which the development proceeds, proportioned to the zoölogical rank of the species.

In minor series we find the same principle; thus the younger periods of *Amm. hybrida*, covering about two thirds of the spiral, have the large, squarely set ribs of the full-grown *Amm. planicosta*, but the adult is remarkable for its flattened sides and Beechean ribs and tubercles. Next in serial order is a species, *Amm. appressus* nobis, MSS.,[1] which has the same Planicostan markings in the young, but they do not take up more than about one third of the spiral, and the rest of the shell is adorned with true Beechean ornaments. This species is absolutely smaller than *Amm. hybrida*, and the shell more involute and flatter.

Finally, we have *Amm. Henleyi*, with a very faint Planicostan aspect at a much earlier period, caused by the prominence of ribs crossing the abdomen and nearly the entire spiral with the Beechean ornaments, and finally *Amm. Beechei* itself, devoid of all resemblance to Planicosta. It is smooth and round at the youngest period, and in course of growth assumes the tubercles, the narrow bifurcating ribs and flattened sides of its species, wholly ignoring the Planicostan stage of the lower members of its own series. This series is one among the Ammonites, in which I have observed no marks of decadence; all is progress, and the phenomena are precisely the same as those brought out in the earlier eras of the rising period of the structure of the Ammonoids. The young of higher species are thus constantly accelerating their development, and reducing to a more and more embryonic condition or passing entirely over the stages of growth corresponding to the adult periods of preceding or lower species.

In other words, there is an unceasing concentration of the adult characteristics of lower species in the young of higher species, and a consequent displacement of other embryonic features which had themselves, also, previously belonged to the adult periods of still lower forms.

This law, applied to such groups as have been mentioned, produces a steady upward advance of the complication. The adult differences of the individuals or species being absorbed into the young of succeeding species, these last must necessarily add to them by growth greater differences, which in turn become embryonic, and so on; but when the same law acts upon some series whose individuals alter the shell in old age, precisely the reverse occurs, and a general decline takes place. The old age characteristics, in due course of time or structure, become embryonic, and finally affect the entire growth and aspect of the higher members of the series.

The Arietes of the Lower Lias, arranged according to their zoölogical affinities, have first

[1] This species will be published in the *Museum Bulletin*.

in order such species as *Amm. Ceras* and *Amm. Conybeari*, which are non-involute, like the Clymeniæ or lower Nautili, and have smooth ribs with a keeled and channelled abdomen; then *Amm. Bucklandi*, *Amm. bisulcatus*, *Amm. Brookei* Sow., which differ from the first in their tuberculated ribs; and finally *Amm. Brookei* Zieten, *Amm. obtusus*, *Amm. stellaris*, and *Amm. Collenotii*, devoid of tubercles and with the ribs more or less depressed near the abdomen. This part, also, becomes narrower than in the preceding species, and in the adult of the last three its channels are lost and the keel is almost obsolete. The deterioration is so extensive and perfect, that *Amm. Collenotii* has been deemed by some authorities one of the Clypeiformi with a smooth, acute abdomen. Both *Amm. stellaris* and *Amm. Collenotii* are more involute than the others, but they have similar septa, and it is difficult to draw the line between the former and some varieties of *Amm. obtusus*, an undoubted Arietian; the thick, depressed ribs of *Amm. stellaris* are traceable, also, upon the sides of *Amm. Collenotii*, although, of course, one degree nearer to absolute atrophy.

In the old of *Amm. Bucklandi* or *Amm. Brookei* Sow., the prominently keeled, flat, and deeply channelled abdomen, and the projecting, tuberculated ribs of the adult may be observed giving way to a narrower abdomen, with a depressed keel and without channels, the ribs obsolete near the abdomen and the aspect of the whorl in transverse section changing from the rectangularity of the adult to a trigonal outline. The increase of the radii of the spiral and the continued complication of the septa are not interfered with, and the shells show no perceptible signs of senility.

These old age peculiarities are identical with those distinguishing the adult of *Amm. Brookei* Ziet., (which is a totally different species from *Amm. Brookei* Sow., separable by reason of the trigonal outline of the whorl and the depressed, smooth ribs of the adult) and *Amm. tenuis* nob. MSS.[1] The latter, however, is deeply channelled in the adult, while the former is so only at an earlier stage, but they both repeat in the young the rectangular whorl of the preceding species. *Amm. stellaris* has the keel and channels more distinct in the young than in the adult, but the form of the whorl shifts at an early period to the senile trigonal aspect and becomes quite involute in the adult. The last is the only characteristic which is not identical with the old of *Amm. Brookei* Ziet. In *Amm. Collenotii* the rectangular whorl is entirely left out of the growth, the transition being gradual from the round embryonic to the senile trigonal, and the channels are only faintly marked in the young. The whole shell is an exaggeration of the old age tendencies of *Amm. bisulcatus* or *Amm. Brookei* Zieten, and the adult is a counterpart of the extreme old age of the involute *Amm. stellaris*, when the ribs are almost wholly obsolete and the sides are partially smooth. *Amm. stellaris* and *Amm. Collenotii*, therefore, are the old age forms of the Arietes series, and they, also, complete the senile tendency shown in the old individual of the lower forms by becoming more involute, — that is, by increasing the radii of the spiral in greater proportion than any other species, and thus responding, as the heads of the series, to the unceasing increase of the radii in the spirals of *Amm. Bucklandi* and the like.

Following the keeled group upwards, the "homomorphs" of the old age forms of the Arietes are found to acquire greater importance, until in the Cretaceous they are represented by an entire series of smooth, involute shells with acute abdomens and no channels.

In the Lower Lias all of the Arietes, with the exception of the two senile forms, are non-involute. The Amalthei of the Middle Lias, however, have but one species, *Amm. Hawsker-*

[1] Also to be published in the *Museum Bulletin*.

ensis with an open umbilicus, the rest, including *Amm. costatus, vittatus,* and *margaritatus,* are progressively more involute with more complicated septa, and their abdomen more acute. Succeeding these are the Falciferi of the Upper Lias, which have but two species, *Amm. Walcotii* and *Amm. bifrons,* that simulate *Amm. Hawskerensis* and the Arietes, and then a long list of others, first with acute abdomens and open umbilici, as in *Amm. striatulus,* then more involute as in *Amm. radians* and *serpentinus,* and finally with the internal whorls entirely hidden, as in *Amm. discoideus* and *Amm. elegans.* The remaining strata of the Jura contain but two or three, like *Amm. cycloides* D'Orb., and some of the so-called varieties of *Amm. Murchisonæ,* which have the abdomen channelled and keeled; their enrolment in all cases, however, that have come under my eye, is more involute than the generality of the Arietes. The Cristati and Clypeiformi constitute the Cretaceous series. The first has a few species, such as *Amm. inflatus* and *Amm. tricarinatus,* which repeat the narrow-whorled Arietes, but only one species, *Amm. tricarinatus,* has the umbilicus sufficiently open to emulate with any accuracy the non-involution of *Amm. Walcotii* of the Falciferi, or *Amm. Conybeari* of the Arietes. The rest are all more involute, and have, in proportion to the radial breadth of the whorls, narrower abdomens. The second series is wholly composed of shells which imitate the old age involution, the smoothness, the obsolescing keel, the obsolete channels, the acute abdomen and trigonal whorl of *Amm. stellaris* and *Amm. Coltenotii.*

Besides these, other instances might be taken demonstrating the incorporation of the degradational characteristics of the individual into the higher forms of succeeding groups, but the brevity of my remarks does not admit such a full illustration of the subject.

One more example is needed, however, to establish the fact, that this incorporation of old age tendencies in the growth of succeeding shells becomes more complete not only as we approach the upper boundaries of the life of the order, but, also, in proportion to our proximity to the termination of the structural cycle among the polar forms.

The senile characteristics of the Clypeiformi are brought out in a manner closely analogous with those of the smooth Nautili, the progress of the septa and form of the whorl in complicating themselves is not sufficiently impaired to afford well-marked degradations, but in the series of shells with round abdomens, like *Amm. Humphriesianus,* a different element is introduced. With them the entire organization appears to have finished its advance and to have begun its morphological decline; the adult era of the collective life of the order is passed, and the coming of its old age era fairly announced. The old of *Amm. Humphriesianus* of the Inferior Oolite, as noticed by D'Orbigny,[1] varies the rate of increase in the length of the radii of the spiral, and ceases to augment the volume of the whorl, which is less involute and more tubular than in the adult. This is attended, as we have seen, by a narrowing of the cells consequent upon the lessening of the space which the lobes have for their expansion. The diminution of the radii in the old of *Amm. dimorphus* and *Amm. Sauzei,* also, of the Inferior Oolite, is more abrupt, and if persisted in would project the last portion of the whorl after the fashion of a Scaphites, or Crioceras. Ascending to the Great Oolite, we find two singular species of the same series, *Amm. microstoma* and *Amm. bullatus,* which are eccentric from an early period. The chambers of *Amm. microstoma,* as they are successively built and left behind in course of growth, become more tubular, and describe curves within the limits of the ideal prolongation of the regular spiral. These chambers are not reabsorbed but remain undisturbed, the animal building onward

[1] D'Orbigny, *Récherches sur les Ammonites.*

from their contracted apertures, and spreading out after each contraction into a broader whorl, which again contracts, and so on. By this process the spiral is reduced to a succession of circular segments, and the symmetry of the logarithmic curve, in which the discoidal forms usually revolve, entirely destroyed. Each segment tends to strike off at a tangent from the main direction of the spiral, but is turned back again toward the centre of revolution at every new season of growth. *Amm. bullatus* caps this series, and the spiral is so deformed by the successive segments, that from the side it has a spherically triangular aspect. The old age features of *Amm. Humphriesianus* are in this way adopted even at a young stage in *Amm. microstoma*, and eventually obliterate the regularity of the spiral in *Amm. bullatus*, because the old age degeneration of the whorl in the first is but a permanent chamber of the same general character with the successive permanent chambers of the two last members of the series.

Amm. terebratus of the Oxford Clay stands intermediate, geologically and zoölogically, between these and the aberrant genus Scaphites of the Cretaceous. The last chamber in which the animal lives bends upon itself, making an acute angle with the preceding portion of the whorl; and since these chambers are probably present at each arrest of development and reabsorbed, as in Scaphites, when the season for growth again returns, the likeness to the latter is perfect. The curve of the last chamber is much within the prolongation of the spiral, and shows the same tendency that was perceived in the growth of *Amm. microstoma* to depart from, and then return toward, the centre of revolution.

The Scaphites come next, and with them the latter part of the whorl actually does strike off at a tangent, but they nevertheless obey the same law, and are forced at last to turn upon themselves toward the centre, forming a kind of shepherd's crook. The whorl is usually more or less flattened, until near the mouth, where it gradually lessens in size and becomes more tubular. They may have upwards of ten lobes as in the adult (*Scaphites constrictus*). Ancyloceras has the whorl tubular throughout, but generally flattened somewhat laterally, and the tangential departure of Scaphites is not only greatly exaggerated in the shepherd's crook of the adult and old, but its effect can be observed in the earliest periods of some species, such as *Ancyloceras Matheronianus* D'Orb., their whorls being separated from the very beginning. None of the species have more than six lobes. The whorl of Hamites has a rounder outline, as a rule, than in Ancyloceras, and the departure is so excessive that the spiral is lost in a succession of straight tubes, making a double shepherd's crook, and there are never more than six lobes to the septa.

In Ptychoceras the shell is yet farther reduced to a single straight shaft with one crook, and in Baculites even this is gone, the spiral tendency of the growth not having sufficient power to produce even the approximation to its former mode of revolution still evident in Ptychoceras. The straight tubular cone, with its usual complement of four to six septal lobes, is all that remains.

The senile tendency of *Amm. Humphriesianus* has gradually culminated in these successive growths until the degeneration of the septa and shell which were primarily indicated in the Inferior Oolite have terminated, as we have previously remarked, in completely uncoiled and rounded whorls and in a number of lobes reduced to the embryonic formula of four or six.

Notwithstanding the accuracy with which these correlations may be followed upward in time throughout the Ammonoid series, they do not necessarily indicate any priority in time for those species which primarily produce the senile characteristics, except in this general series.

In other series, such as the Arietes of the Lower Lias, we have in the same formation, and side by side, embryonic, adult, and old age forms, and among the Nautiloids the old age forms actually precede in the Silurian the great display of the fully ornamented adult forms of the Carboniferous.

I can only claim, therefore, that there is a correspondence between the manifestations of decline in the individual and in the degradational features of the group, whether these appear early or late in time.

It may be said that the smoothness of the Lævigati in the Nautilian series is entirely due to a retention of embryonic characters throughout life; and their early advent in the Silurian certainly affords good grounds for such a conclusion. On the other hand, however, their development, omitting as it does the characteristics of the straight Endoceras and Orthoceras, seems to identify them with such undoubtedly senile species as *Amm. obtusus*, or *Amm. stellaris.* The resemblance of the adult features of such species to the old age characteristics of lower species are too clear to be accounted for by an arrest of development; unless, indeed, we can assert that the resemblance of the old and young in the same shell is due to an arrest of development, which would be a manifest absurdity.

I have been dealing so far with but one organ, the shell; and notwithstanding the utmost care and frequent reviews of the specimens themselves, I have found that the facts always revealed the same laws, and ever more decidedly. But some time since I satisfied myself that if the softer parts had been preserved, one of my conclusions would have received important qualifications. In order to obtain an adequate illustration of this, I will conclude with one or two examples from existing animals.

Mr. Morse, besides elucidating the general homologies of the Saccata, shows with the greatest clearness that the Cephalopod is very similar in form to the Polyzoon, although completely reversing its structure.[1] Thus, while both are sacs closed at one end by a disc perforated by the mouth and fringed with a circular crown of tentacles, and their alimentary canals bent in a similar way and opening in the vicinity of the mouths, one is a perfectly cephalized, and the other an anti-cephalic type. The nerve-mass of the Cephalopod is situated at the anterior, and in the Polyzoon at the posterior pole; and while in the former the anus and intestine are on the ventral side, in the latter they are on the dorsal side. By entirely revolving the positions of the principal organs a morphological polarity is established in the Cephalopod; which being the structural reverse of the Polyzoon is yet so alike in shape, that either a longitudinal or transverse section of the body has the same outline. The element of time being eliminated, these polarities are related morphologically to the intermediate members or classes, as the aberrant Ammonoids and Nautiloids were to the normal forms; they are organically removed from each other to the greatest possible degree, being at the extremes of the Saccate type.

It will be remembered, also, that the polarities were brought about by a revolution of the straight cone into an involute cone, and subsequently from the involute to a straight cone again. The intermediate steps of the revolution of the organs between the Polyzoa and Cephalopoda exhibit the action of the same law.

Mr. Morse's figures in the single plate attached to his paper give us a distinct idea of the successive changes in this remarkable series of transformations. The anus remains more or less posterior, and the oral region with the other organs is carried by a cephalic

[1] E. S. Morse, *Proceedings Essex Inst.* Vol. iv., p. 6, 1865.

concentration towards the anterior pole of the Brachiopoda; the anus remains posterior and the oral region is yet more anterior in the Ascidia; the anus is posterior and the oral region opens at the anterior end in the Lamellibranchiata. At this point the revolution of the mouth stops, it having been transferred from the posterior pole of the Polyzoon to the anterior pole of the Lamellibranchiate along the ventral side, and the revolution of the anus may be said to begin. This follows the mouth along the ventral side and in the Gasteropoda and Cephalopoda opens in proximity to the latter on that side, thus completing the inversion.

What effect old age may have upon the individual, and what may be its correlations with polarities upon such a vast scale, are questions that I am at present unable to answer in a satisfactory manner.

One fact, however, is worthy of notice and exceedingly suggestive. The initiatory transformations described above are due to cephalic concentration, a retraction of the whole body within the cœnœcial or mantle region. This is the permanent position of the Polyzoon at the two extremes of its life, during its old age, and while it is still an embryo.[1] The Brachiopoda have been homologized by Mr. Morse and myself,[2] and the Ascidia by Prof. Allman[3] with an invaginated Polyzoon on account of this very cephalic concentration; and what is still more curious, the Brachiopoda, which most nearly resemble the invaginated individuals of the Polyzoa, are those that betray an old age peculiarity. It is well known that the old individuals are more globular than the adult or young,[4] and the forms which have the simple dorsal flexure of the intestine and the oral disc or lophophore extended into horse-shoe shaped arms fringed with tentacles, as in the Hypocrepian Polyzoa, are the Waldheimia, and Terebratula, — exceedingly globular and deep shells. Whatever may be the value of these suggestions, it certainly seems that the Polyzoa assume in old age, as described by Milne Edwards in the genus Eschara, a much higher state, withdrawing themselves into their cephalic regions, and in this condition are more closely allied to the Brachiopoda or Ascidia than at any previous time of life.

There are other polarities which are similarly placed in their respective divisions. The Dibranchiate Cephalopoda are, also, the polar forms of the Pteropoda, which are at the foot of the series of cephalized Saccata. The general aspect, the arrangement and position of the oral region, and the disposition of the internal organs, are similar in both. The Limacidæ are the polar forms of the Nudibranchiata, the former ending the series of intermediate shell-covered Pulmonifera, and the latter beginning the series of shell-covered Branchifera. The shell-bearing Pulmonifera, and Branchifera have equivalent features and are the normal turbinated Gasteropoda. The polar extremes, where all the viscera and the coniform mantle of the turbinated Gasteropoda are condensed into the cavity of the foot, have a much more embryonic appearance than the intermediate norms. According to the observations of Lereboullet upon the development of Limneus stagnalis,[5] the foot is observable at a very early age, before the internal organs, with the exception of the alimentary sac, are defined, or the spiral tendency of the growth is manifested; and the whole yolk, in fact, is first only part of a creeping disc. The Medibranchiata and Limacidæ are only creeping discs, with the viscera in place of the yolk, and must, therefore, mor-

[1] Milne Edwards. *Annales des Sci. Nat.* Tom. vi. 1836.
[2] Hyatt. Observations on Polyzoa. *Proc. Essex Inst.* Vols. iv. and v. 1865–6.
[3] Prof. Allman. *Monogr. Fresh Water Polyzoa*, Lond., 1856.
[4] Woodward. *Recent and Fossil Shells*, p. 213.
[5] Lereboullet. Embryol. du Limnée des Étangs., *Ann. Sci. Nat.*, 4e Sér. Tom. xviii. 1862.

phologically be deemed more embryonic than the normal spiriform and turbinated shells, notwithstanding the elevated structural position and functional superiority of the Limacidæ. We reduced the morphological polarities of the Tetrabranchiata to the same law. It was, however, impossible then, in dealing with the shell alone, to perceive, as we did in this or in the case of the reversional polarity of the Cephalopod to the Polyzoon, that the polar forms might be structurally and functionally higher than the norms, although the latter might be, with respect to the structure of some parts and their general morphological peculiarities, less embryonic and apparently more complicated. There is undoubtedly a direct structural degeneration of the septa and form among the aberrant Ammonoids; but it is probable that their structure as a whole is deserving a higher zoölogical rank than the seemingly more complicated Ammonites; just as the Cephalopoda or the Limacidæ are secured in their respective positions by the balance of the organization, in spite of their morphological reversions to prototypic forms.

These remarks being simply preliminary, I have not thought it appropriate or necessary to discuss doubtful points of classification, or to extend the subject to all its applications, preferring to leave a fuller consideration until I shall have completed the publication of the catalogue of the Cephalopoda, referred to previously as partly ready for publication in the *Bulletin* of the Museum of Comparative Zoölogy. Facts, however, have been brought out which sufficiently show that there are correlations between the two modes of manifesting vitality in the cycle of a single life and that of the collective life of the group to which the individual belongs.

VIII. *Observations on the Glacial Phenomena of Labrador and Maine, with a View of the recent invertebrate Fauna of Labrador.* *By* A. S. Packard, Jr., M. D.

Read October 4, 1865.

I. Observations on the Glacial Phenomena of Labrador and Maine.

In its general features the Peninsula of Labrador is an oblong mass of Laurentian rocks lying between the 50th and 60th parallels of latitude. It rises abruptly from the ocean as an elevated plateau, forming the termination of the Laurentian chain, which here spreads out into a vast waste of hills and low mountains. Thus, there is no well-marked, single chain of mountains rising above spurs of smaller elevations, but simply a height of land with isolated peaks, irregular in its course, from which streams take their rise and flow by various directions into the ocean.

This plateau of hills and low mountains rises abruptly on the coast from the ocean to a height of 500 to 800 feet, and inland continues to rise in peaks to a height of from 1500 to about 2500 feet until it reaches the water-shed at a distance of 100 to 200 miles from the coast. On the western slope this plateau falls gradually away by an easy descent towards the shores of Hudson's Bay.

On the south, the coast has a northeasterly trend, following the coast line of the southern Atlantic border of the continent. From Belle Isle, situated at the mouth of the Straits of Belle Isle, the eastern coast trends in a northwesterly direction to Cape Chudleigh, thus following the northwesterly trend of the northern Atlantic coast line of the continent from Cape Race in Newfoundland to the head of Baffin's Bay, near latitude 80°. It thus lies parallel to the western coast of Greenland. The northeasterly trend of the southern coast of Labrador is determined by the same course of the Laurentian range of syenites and gneiss rocks, which forms the northern shore of the St. Lawrence Gulf and River. Its northwesterly course beyond the Straits of Belle Isle is likewise determined by a range of syenites and trap rocks, upheaved in a general N. W. and S. E. direction. Thus the interior plateau of Laurentian gneiss seems surrounded by a framework of igneous rocks, which has apparently preserved to this day the original form and proportions of the Atlantic slope of the azoic nucleus of our continent.

Parallel to the Straits of Belle Isle and situated about 100 miles from the coast, is an important water-shed which terminates in a spur of high peaks, called the Mealy Mountains, which on the southern shore of Hamilton Inlet (Invuctoke Bay) rises 1500 feet, it is said, above the level of the sea. Numerous rivers descend the steep southern slope into the St. Lawrence. Of these the River Moisie and Esquimaux River are the largest. They arise from a chain of lakes on the summit of the water-shed, from 100 to 200 miles in the interior, which also give rise to a still larger river which flows into Hamilton Inlet and bears the same name. I have been informed by residents that the Indians can travel in their canoes from the mouth of the Esquimaux River across the country to the Hudson Bay Posts in Hamilton Inlet. Professor Hind,[1] and Mr. Cayley[2] likewise state that the head waters of the River Moisie lie contiguous to those of the two above named rivers — if the source of all the three rivers be not the same. The Moisie River forms part of the

[1] *Explorations in the Interior of the Labrador Peninsula*, 2 vols., 8vo., London, 1863.

[2] *Up the River Moisie.* By Edward Cayley. Trans. Lit. and Hist. Soc., Quebec, N. S., vol. i., p. 73.

St. Lawrence river system. It is 125 miles long, and flows south, emptying into that river near the Bay of Seven Islands, at a point west of Anticosti and opposite the northern shore of the Gaspé Peninsula. From this point the streams running into the Gulf assume, the farther we go east, a N. W. and S. E. direction. Such is that of the Meschikimau or Esquimaux River, which empties into the western mouth of the Straits of Belle Isle, at the lower Caribou Island.

This stream is about 250 miles long, as I learned from residents, and is only navigable for about twelve miles from its mouth by ordinary fishing-boats. There is no large river between this and Hamilton River which flows into the Atlantic in a direction a little north of east. This river seems to flow in a fissure that runs at right angles to the line of upheaval of the syenite and traps of the Atlantic coast; as upon the Gulf coast the rivers flow from the northwest along natural fissures in the earth's crust that run at right angles to the axis of elevation of the Laurentian chain on the north side of the St. Lawrence. In this connection it should be noticed that the fiords on the Atlantic coast of Labrador assume the same direction, and though they agree much in this respect with the direction of those farther south, there is yet a greater west and east course as we go northward towards Cape Chudleigh, until beyond lat. 58° the fiords run in a N. W. and S. E. direction, especially on the Hudson Bay slope. According to Davies[1] the Grand or Hamilton River is supposed to rise from a chain of lakes in the "rear of the Seven Islands, and flows for a considerable distance on the top of the ridge, if I may so express it, between the head waters of the rivers falling into the St. Lawrence and those falling into the Hudson's Bay and Straits, for they are said by the Indians to be quite close to the waters of the Grand River on either side." Our author also states, that "two hundred miles from its mouth it forces itself through a range of mountains that seem to border the table land of the interior, in a succession of tremendous falls and rapids for nearly twenty miles. Above these falls, the river flows with a very smooth and even current."

Two other important rivers empty into Invuctoke Bay: the Kenamou, which flows in from the south, and the Nascapee or Northwest River, which is a larger stream with a very circuitous southeasterly course.

The Atlantic system of streams to the north are small rivers flowing into the ocean in an easterly course.

Ungava Bay receives two important rivers which imperfectly drain the northwestern slope of western Labrador. The smaller of the two is the Kangutlualuksoak or George River, which empties into the bay in lat. 58° 57′, and is 140 miles long. Its water-shed is said by Kohlmeister and Knoch[2] to be a chain of high mountains which terminates in the lofty peaks of syenite at Aulezavic Island and Cape Chudleigh, which are the highest mountains in Labrador, and rise probably over 3000 feet in height, as the smallest of them, Mount Bache, was measured in 1860 by the Eclipse Expedition of the U. S. Coast Survey, and found to be 2150 feet high. This mountain is a gneiss elevation, and a sketch on the geological chart by Mr. Lieber, the geologist of the expedition, shows it to be rounded by glacial action, while lofty, "wild, volcanic-looking mountains" form a water-shed in the interior, whose craggy peaks have evidently never been ground down by land-ice into

[1] *Trans. Lit. and Phil. Soc.*, Quebec, vol. iv. p. 70, 1843.

[2] *Journal of a Voyage from Okkak, on the Coast of Labrador, to Ungava Bay, westward of Cape Chudleigh, undertaken to explore the Coast, and visit the Esquimaux in that unknown region.* By Benj. Kohlmeister and George Knoch, Missionaries of the Church of the Unitas Fratrum. London, 1814.

domes and rounded tops. The two Moravian missionaries, mentioned above, state in addition, that "this chain of mountains may be seen from the Kangutlualuksoak River, in Ungava Bay, which is a collateral proof that the neck of land terminated to the north by Cape Chudleigh is of no great width. Both the Nain and Okkak Esquimaux frequently penetrate far enough inland to find the rivers taking a westerly course, consequently towards the Ungava country. They even now and then have reached the woods skirting the estuaries of George and South rivers." These missionaries describe the Koksoak or South River as flowing smoothly through a low, rocky (probably Silurian) district, and emptying into Ungava Bay in lat. 58° 36′. It is said to resemble at its mouth the Thames, and affords anchorage for vessels twenty-four miles from its mouth. This stream probably arises near the source of the Grand or Hamilton River, and flows in a N. N. W. direction, probably along a natural fissure formed by the juncture of the Silurian rocks and Laurentian system.

At the western political boundary line between Labrador and Prince Rupert's Land, according to recent maps, we find apparently another water-shed, which on the eastern slope sends a few streams into the Koksoak River, while on its western slope descend several streams which flow in a westerly course into Hudson's and James Bay.

Thus it will be seen that these four river systems take their rise from a great water-shed which curves in a southwesterly direction from Labrador along the northern shores of the St. Lawrence River and the Great Lakes.

Labrador is essentially a *lake* district. Its numerous rivers afford a very imperfect system of drainage to a country densely covered with lakes, ponds and pools, and morasses innumerable. It resembles in this respect the probable aspect of the Lake or Terrace period in New England and Canada after the Glacial period, when the present broad rivers were only chains of lakes, and may thus be said to be in an embryonic stage, as its river-beds have never been remodelled and scooped out into gentle declivities and broad valleys, nor immense depths of sand and clay deposited to smooth over the inequalities of the rocky surface of the country, such as in the temperate zone render a continent inhabitable throughout its breadth; while in Labrador man can only inhabit the coast, and gain a livelihood from the sea.

We must distinguish two classes in the lakes of Labrador, viz.: the deep mountain *tarns*, lying in the interior, directly upon the summits of the water-sheds; and the far more numerous broad, shallow lakes and pools spread profusely over the surface below the height of land. These last occupy shallow depressions and hollows, most probably excavated by glaciers, in valleys which have been simply remodelled by glacial action. The deep tarns, on the contrary, evidently fill original depressions, sinking between lofty ranges of hills. Davies says that in the region about the source of the Hamilton River the lakes are very deep, and lie directly on the height of land, while the ponds on the lowlands are shallow; and on the other hand, those which directly communicate with the ocean or with the fiords are in general distinguished for their depth. "This almost universal shallowness of the lakes is a singular feature, when the nature of their borders is taken into consideration, as they are generally surrounded by hills, which would lead one to look for a corresponding depth in the lake; but, instead of this, some are so shallow, that for miles there is hardly water enough to float a half-loaded canoe. I am informed by my friend John McLean, Esq., that this is likewise the case with the lakes lying on the water-shed of Ungava Bay. The lakes, lying *on* the table-land are said to be deep."[1] He also states that

[1] *Loc. cit.* p. 76.

the large lakes in the interior are well stocked with fish, while the shallow lakes, and, in fact, the deep ones communicating with the ocean, are in general very destitute of them.

We must believe that the same causes that produced the deep fiords likewise account for these deep fissures and depressions in the summit of the water-sheds. It is evident that any amount of glacial action, however long sustained and vast in its operation, can never account for these rude, irregular, often "geoclinal" troughs which follow lines of fracture and faults, lying along the axis of elevation of mountain chains, or at nearly right angles to them.

The fiords on the Labrador coast are of great extent and depth. They are either original lines of fracture and faults, or what Professor Dana terms *geoclinal* troughs, occurring at the line of juncture of two rock formations. Thus Chateau Bay is a fissure at least 1200 feet in depth. The western shore rises 600 feet above the sea level, and the waters of the bay at their deepest are 600 feet in depth. This fault must have been produced at the time of the upheaval of the syenites of the coast.

All the broad, deep bays and fiords on the Atlantic Ocean occur at the juncture of the syenites and gneiss rocks, or juncture of quartzites and their trap overflows. There are deep bays between Cape St. Lewis and Cape St. Michael's, where syenites rise through the gneiss, producing faults and lines of dislocation. The large bay just north of Cape St. Michael's occurs at the junction of gneiss and "hyperite" rocks. Sandwich Bay and Hamilton Inlet were formed by the denudation of the Domino Quartzites. Despari Harbor is a deep fiord occurring at the juncture of the "Aulezavic Gneiss" of Lieber, with syenitic rocks forming the coast line between this point and Hopedale. The irregular overflows of trap and syenitic rocks which enclose the gneiss rocks, produce an immense number of cross fiords and channels, from the presence of innumerable islands which line the coast, and are composed of these eruptive rocks.

These original fissures and depressions have been modified by glaciers, by frosts and shore-ice and icebergs, and the waves of the sea.

The shallow lakes, formed most probably by glaciers, lie in shallow troughs, upon a thin bed of gravel and boulders. We only learn in some regions, especially in Southern Labrador, that the country has been covered with boulders, by their presence on the banks and in the centre of these pools. Clear examples of lakes partially surrounded by walls of rock, with the banks at one end completed by a barrier of sand and gravel, are frequent. Such barriers of drift have lost entirely their resemblance to glacial moraines, to which they undoubtedly owe their origin, since the drift deposits have been remodelled into sea beaches composed of very coarse gravel and boulders, while the finer materials have been swept away by the powerful "Labrador Current" with its burden of icebergs and floe-ice that has so effectually removed traces of the former presence of what we must believe to have been extensive glaciers.

Azoic Rocks of the Labrador Coast.

Laurentian Gneiss and Syenite. Between Little Mecatina Island and Henley Harbor, there is a great uniformity in the rocks, which are either wholly gneiss, or more commonly a syenitic gneiss, forming bold headlands. At Bradore are two lofty hills of gneiss, estimated by Bayfield to be 1200 feet high. Between Belles Amours and Anse au Sablon, on the northern side of the Straits of Belle Isle, occur the lower Silurian or Taconic rocks which have been already fully described in the "Geology of Canada," published by the Canadian

Geological Survey. In coasting within a mile or two of this interesting region we see the red sandstones running out as a low point of land resting on the lofty, precipitous Laurentian rocks. Between Bradore Bay and Anse au Loup these sandstones and grits rise up to a height of 500 to 600 feet, forming the coast line; and looking up through the bays and harbors we can see the low conical hills of Laurentian gneiss in the interior. At the eastern termination of this formation, the Laurentian rocks rise into high, rugged and broken syenitic hummocks, in marked contrast with the regular terraces and smooth slopes of the fossiliferous sandstones and limestones. Approaching Henley Harbor, there is a visible change in the scenic features of the coast; the hills grow more regular in outline, and slope gradually to the water, giving us the peculiar physiognomy of the Laurentian gneiss.

Upon entering Henley Harbor the dark gneiss is seen resting upon syenite, and at the point of contact interpenetrated by irregular intrusive masses of the latter rock. On Henley Island, where these rocks crop out under the trap capping this island, there appears a true syenitic gneiss, very hard, distinctly stratified, and of the usual flesh color of the syenite.

At this point I broke off some pieces of nearly unstratified syenite which showed very distinctly the sedimentary origin of the rock, for the crystals were often partly rounded and contained rolled quartz pebbles, one being ovate and nearly two inches long. This syenitic gneiss was evidently an altered conglomerate.

The syenite is the same as occurs on the coast of the St. Lawrence River, and while of the same color as that of the Maine and Nahant syenite, differs in its greater hardness and in the absence of black hornblende. It is composed of a flesh-red labradorite or soda feldspar and a smoky and glassy quartz with minute particles of hypersthene disseminated sparsely through the mass. It is exceedingly tough and durable, as evidenced by the lofty capes and islands standing far up above the gneiss rocks spreading around the base of the overflows.

At the northern end of the island the syenitic gneiss dips under the trap in a southeasterly direction at an angle of 50°. On an island a few rods farther to the north, the gneiss assumes its usual character, being banded with light and dark strata, and has the general N. N. E. strike and dip indicated above.

At Square Island, which lies at the mouth of a deep bay just north of Cape St. Michael's, occurs in large, conical hills the great *anorthosite formation* of Logan and Hunt, composed of large, crystalline masses of labradorite, with a little vitreous quartz, and coarse, crystalline masses of hypersthene. The labradorite is of a smoky color, very lustrous, translucent and opalescent, with cleavage surfaces often two inches in diameter, and on some of the faces presents a greenish reflection. This is but a slight approach to the rich blue reflections of the precious labradorite which I have seen only at Hopedale, where we obtained specimens brought from the interior by the Esquimaux. It compared favorably with specimens from the Ural Mountains.

As the rock weathers, the hypersthene crystals project in masses sometimes two inches in diameter. This rock easily weathers, and large masses are detached by frosts and readily crumble to pieces. The gneiss rests on the south side of the hill. From the top of the hills here can be seen huge gneiss mountains at least 2000 feet high, rising in vast swells at a distance of fifteen to twenty miles in the interior, while the bay is filled with innumerable *skiers* and islets of gneiss.

At Cape Webuc or Harrison, the gneiss again appears upon the coast as a lofty headland faced with steep precipices of syenite. From off this cape are seen in the interior lofty mountains, of which the central and highest peak is called Mount Misery, which in this clear climate can be plainly seen in pleasant weather by fishermen at a distance of seventy-five miles in an air line. At Strawberry Harbor on the south side of Thomas Bay are lofty syenite hills. This point is fifty-five miles north of Cape Webuc. It is a small deep hole in the coast, like a "purgatory," and an amphitheatre of rock rises around it in huge steps, affording a striking illustration of the power of the frost and waves on this exposed coast. The rock is a hard tough flesh-colored syenite, with deep vertical and horizontal fissures resulting from the decomposition of thin trap dykes, thus causing huge blocks of syenite to be detached and fall down. In sailing twenty-five miles up this bay, the gneiss rises on each side from the ocean into hills 800 to 1000 feet in height. About Hopedale, which is in latitude 55° 30′, the rocks are gneiss. Behind the Mission House the strata are much disturbed locally; at one locality the gneiss with veins of quartz and syenite trends northwesterly and dips 60° west. Trap dykes, prismatic in places, cross the island in a northeasterly direction.

Northward of Hopedale the "Aulezavic gneiss" of Lieber, forms the coast range of mountains, which, according to Lieut. Curtis (Trans. Geol. Soc. London, Vol. ii. 1773), rise to a height of 2733 feet at Mount Thoresby, on an island south of Kiglapyd. This observer states that Kiglapyd is evidently higher, but inferior to Kaumagok, which "has been seen thirty leagues from land," and is lower than Nachvoak which must be 3000 feet high.

At Aulezavik Island near Cape Chudleigh, according to Mr. Lieber,[1] "syenitic gneiss is the true rock of the region, the normal one, although so many modifications occur that entirely new rocks are produced; having no direct connection with the basic syenitic gneiss. In consequence of this we have beds in which quartz alone occurs, or beds entirely occupied by the red feldspar of the region, as is seen with very beautiful distinctness in some of the dangerous Pikkintit Islands. Again, some beds are composed of white quartz and tourmaline as in Norway, others contain scarcely anything but black hornblende, or tourmaline and garnets. Some are composed of green hornblende, approximating to actinolith. From this there seems to be a passage into a coarse diorite rather porphyroid in its character, but occurring in regular intercalated beds, not in dykes, and evincing no sign of an eruptive origin. Again, some beds are composed of quartz and garnet, while others are studded with a beautiful golden-colored mica. A rock which appears identical with aphanite, although not at all igneous, I also found, yet, with all this apparent variety, the transitions are too gradual to permit the differences to leave any effect on the landscape."

For some notes on the geology of Hamilton Inlet we are indebted to Mr. Davies — "In some places mica slate was found — it is said that the Mealy mountains are composed of this rock. I had no opportunity of verifying this fact, as I did not visit them. Granite was only seen in one place, viz., on Lake Keith, an expansion of the Grand River, about one hundred and thirty miles from its mouth. Specimens of Chlorite schist were also procured on this lake, as was also a specimen of sandstone, with disseminated grains of iron pyrites. At some distance below the lake, Primary Marble, of a beautiful whiteness, was seen cropping out at the edge of the water; it was found in contact with a quartz rock passing into mica slate, having crystals of common garnet imbedded in it; this was the only place where limestone of any sort was seen.

[1] *Loc. cit.*, p. 405.

The shores of the bay where they are not of rock are generally composed of rolled fragments of syenite, mica-slate, quartz, hornblende, sometimes in large masses, feldspar, &c. Magnetic iron in the form of sand was also met with in some of the small coves.[1]

Laurentian Trap Rocks. At Henley Harbor is a system of trap rocks which have been upheaved in a N. N. E. and S. S. W. direction, in a course much more northerly than the direction which the Straits of Belle Isle assume. These rocks consist of three masses of columnar basalt, capping the syenitic gneiss. It is a hard fine compact diorite, breaking with a conchoidal fracture and metallic ring, and contains much iron. The mass is 255 feet high on Henley and Castle Islands, and consists of two layers of vertical columns. West of these basaltic rocks, on the opposite side of the harbor, is a large trap overflow forming a hill over 300 feet high, and apparently of the same age. It should be remarked that the two layers of basalt representing successive overflows, incline at a very slight angle towards the S. W. The third mass of basalt is seen rising out of the ocean a few miles northerly, nearly in a line with the basalt of Henley Harbor.

Dykes of this age are likewise seen at Strawberry Harbor, Cape Webuc, and at Hopedale, intersecting the Laurentian gneiss and syenite. Its age is plainly anterior to the deposition of the undisturbed Taconic, "primordial" strata at Anse au Loup, and on the Newfoundland coast opposite.

Huronian Group. A system of quartzite and trap rocks which lie in a depression of the Laurentian rocks, about one hundred and twenty-five miles long, and probably twenty-five miles broad, stretching along the coast between Domino Harbor and Cape Webuc, I refer, with some hesitancy, to the Huronian series of Sir W. Logan, and consider as probably equivalent to the "Quartzose Division of the Primitive Slate formation" of Naumann and Keilhau.[2] It agrees in part with the "Domino Gneiss" of Mr. Lieber.

At Domino Harbor in lat. 33° 30″, the quartzose rocks attain their greatest development, occurring as a slightly schistose light colored quartzite, the base of which is a white granular vitreous quartz, with speckles of black hornblende, and more rarely still, minute particles of hypersthene, with a few particles of a lilac colored mica. There are also minute rude crystals of yellow garnet, or cinnamon stone, disseminated through the mass. No feldspar was detected in this rock. In some places the rock was exceedingly fine, in others, it assumed almost a conglomeritic aspect, from the presence of small pebbles of quartz. The quartz is often colored green. This rock weathers easily, leaving masses of quartz projecting on the surface; it is comparatively soft, and has been greatly denuded. It thus forms at this locality a broad low flat plain about ten miles broad and fifteen to twenty miles long, through which rise bosses of diorite. Its surface is but a few feet above the level of the sea, and to one just coming from the high coast to the southward, this broad naked flat, almost wholly destitute of vegetation, with no valleys to shelter even a growth of spruce trees, and but slightly furrowed by glacial action, with patches of white rock glistening in the sun from between the dull green morasses and ponds that are everywhere scattered over its surface, — presents a strange and foreign feature of the coast scenery, startling from its very tameness. When in contact with the trap hills the rock is much harder, rising into higher elevations.

Nowhere was I able to see the juncture of this rock with the Laurentian gneiss, which rises from the edge of this formation into high hills and mountains. So smooth had this

[1] *Loc. cit.*, p. 81.

[2] See T. Macfarlane, on the *Primitive Formations in Norway and in Canada.* Canadian Nat. and Geol., vol. vii. 1862.

plain been levelled and worn by glacial and aqueous agents, that it was difficult to observe the dip and strike of the beds, which, when undisturbed by eruptive rocks, I am inclined to believe, dip easterly at a slight angle. At Dumplin Harbor, which is a bight in an island lying just S. E. of Huntington Island, the quartzite, when lying next to trap, approximates to gneiss in its character, under which it dips at an angle of 35° S. E., the strike of the beds being northeasterly. At Tub Harbor these rocks come in contact with the Laurentian syenite. Between the quartzites were beds of a dark fine-grained hornblendic quartzose gneiss, capped by the syenite. At Indian Harbor, about thirty miles north of Tub Harbor, and on the opposite side of Hamilton Inlet, these same rocks appear. These rocks occur also at Sloop Harbor, rising two hundred feet high, and are capped by syenite, which is very pale in color, with particles of black hornblende. Here, as at Tub Harbor, the quartzite at the point of contact with the syenite becomes a dark gneiss. The Esquimaux Islands which lie off this coast, are composed of the light colored quartzite which here seems to assume the character of a true gneiss. At no point was I enabled to observe whether these quartzites rest unconformably upon the older Laurentian gneiss, though strongly inclined to think so.[1]

Invariably accompanying these rocks is a dioritic trap of a peculiar mineralogical character, occurring in overflows of a peculiar physiognomy, and upheaved in a direction at nearly right angles to that of the Laurentian dykes, thus following the general northwesterly trend of the Atlantic coast of the Peninsula.

This rock differs from the hard fine-grained trap at Henley Harbor, in being coarsely porphyritic. It is composed of large crystalline masses of hypersthene and labradorite, this last being of a dark smoky color, and precisely such as described as occurring in the hyperite of Square Island. It seems to follow that this porphyritic trap is the result of the refusion of the anorthosite rock, which must consequently underlie this Domino quartzite. This is an argument for the unconformable bedding of this quartzite upon the lower Laurentian gneiss, while this trap rock is evidently of the age of the former quartzose rock, which it has somewhat disturbed. The Isle of Ponds is largely composed of these trap hills. Huntington Island is a large mass of trap. Tub Island, as its name betokens, is a peculiar, truncated cone of trap, resembling an inverted tub. These trap overflows extend northward to Cape North, which is a lofty headland of trap capping the gneiss, and thus adding very materially to the elevation of this, as of all the other numerous gneiss promontories which run out from the main land. Occasionally an island is seen half black and half white, one side being composed of the dark trap rock, and the other of the light colored quartzite. Such is "Black and White," a very prominent island near "Indian Tickle," a harbor at the northern side of Hamilton Inlet. Here are some remarkable dykes which ascend the gneiss hills in huge irregular zigzag crests, often crossing each other at right angles.

Beyond this point the Laurentian gneiss again appears, and forms the high bold shores extending to Hopedale, rising in the interior into lofty imposing mountains on whose tops lie patches of snow.

Among the erratic rocks at Domino Harbor were some which show that in the interior are beds of jasper and chert. There occurred several small boulders of jasper and gneiss. The jasper was pale green, banded and striped by darker shades of green, while the

[1] The Canadian Geologists likewise state that the strata of the Huronian system have not been observed resting *directly* on tilted Laurentian rocks; it is as yet a matter of hypothesis.

irregularly alternating bands of syenitic gneiss appeared to be an altered quartzite, as it was found under a glass to be largely composed of a fine granular quartz rock, with a little flesh colored and white feldspar, and minute particles of hypersthene.

Several boulders of chert occurred at Tub Island. This was a very tough compact silicious rock, lineated by fine veins of quartz. It weathers to a dull chalky white.

It is most probable that these rolled stones were borne down from the interior by glaciers, but the chert pebbles may have been borne on floating ice from Frobisher's Bay, as Mr. Hall notices such rocks as being abundant there. At Tub Island I was shown specimens of magnetic iron ore, which were brought from "Cartwright's Tickle," a few miles toward the main land. It occurred in veins half an inch wide.

Should further search prove the existence, in connection with this quartzite, of beds of a true conglomerate, which we should look for in the interior, and of the presence of copper ore in connection with the quartz veins near the trap rock, the identity of this formation with the Huronian rocks of Canada and similar rocks in Sweden would seem satisfactory; and if proven, will be interesting not only to the geologist, but be of practical value in the search for ores on this coast.

Quaternary Formation.

In studying the drift phenomena of Labrador as compared with those of the temperate zone, we shall at the outset find ourselves disappointed in our anticipations as to their relative development. In a region which has evidently been exposed to the most intense action of glaciers, prolonged over a period vastly longer than in Canada or New England, we have surviving this period of denudation and wasting away of the surface, but few drift scratches remaining on any exposed surfaces below a height of 500 feet above the sea; and superficial deposits which are reduced almost to a minimum as compared with those of the temperate zone.

In this absence of drift and more recent deposits, the Labrador plateau agrees exactly with all mountainous districts, above the level of most deciduous trees. We are to look to the lowlands about their base for the debris and drift borne down by streams or glaciers from the mountain centres. The Labrador plateau has been greatly denuded. Its highest mountains have been truncated, and their peaks sliced off by the denuding agent as if by a knife. The quartzites of Domino have lost at least 300 to 400 feet of their comparatively soft strata, as evidenced by the lofty trap hills which now rise above the strata of altered sandstones. The trap is as firm and hard at the top of the overflows as at the base. The loose material resulting from this long continued denudation is not now found in the interior or on the coast of Labrador, except in very small quantities. It was evidently conveyed southwards by icebergs and floe or shore-ice, and forms the bottom of the St. Lawrence Gulf, and the banks and shoals southward. In most subarctic and all arctic lands the soil is but a few inches deep.

In all temperate regions the superficial deposits have been characterized by Prof. Desor[1] to be "a succession of rocky hills and drift plateaus or valleys, which can be traced to the highest elevation of the country, near the dividing ridge, each following plateau or valley being commonly at a higher level than the preceding." This state of things obtains in Labrador, but there is an immense disproportion between the rocky hills and the drift deposits. We find no sandy plains or level tracts of glacial drift, or marine clays, distributed

[1] Foster and Whitney's *Report on the Geology of Lake Superior.*

at intervals from the coast to the interior. They take the form of occasional, isolated sand-banks and cliffs of clay, of slight extent, overhanging rivers, and which by their secluded and retired positions have escaped the general denudation by the Labrador current which must have passed over the lower levels of the Peninsula subsequent to the glacial epoch. In travelling in the interior we find ourselves walking, when it is possible to walk or climb at all, over the rocky floor of this inhospitable region, smoothed in spots, though rarely striated by glaciers, but on the coast more generally mangled and torn by the action of shore-ice and frosts, which have here shown a vast power.

The Leda clays are mostly confined to the head of retired bays, or if in more exposed situations, lie between bold headlands. Those vast sand barrens of Canada and New England spreading into broad plains, are here represented by precipitous masses of sand hanging upon the steep mountain slopes. The traveller stumbles upon them in ascending the swift impetuous streams.

The most abundant superficial deposits in Labrador are the ancient sea-beaches, which are found, according to Prof. H. Y. Hind, at all levels to a height of 1200 feet above the sea, at a distance in the interior of one hundred and twenty-five miles from the coast. They are evidently altered glacial moraines.

Glacial Epoch. Drift Striæ and rounded Rocks. The whole Labrador Plateau has been moulded by ice to a height at least of 2500 feet above the level of the sea. The gneiss mountains are moulded into large flat cones, often with a nipple-shaped summit; the syenites are either moulded into domes or into high conical sugar-loaves; the anorthosite syenite at Square Island occurs in high rude cones; and the trap overflows accompanying the Domino quartzites form rough irregular bosses. Only at one point near the northern termination of the Peninsula at Cape Chudleigh, have the mountains by their altitude escaped the rounding and remodelling action of glaciers. These scraggy peaks, covered with loose square blocks detached by frosts from their slopes, remind us of the summits of Mount Washington in New Hampshire, and Mount Katahdin in Maine. In a sketch of the former mountains by Mr. Lieber, as given in the "Report of the Coast Survey," the transition from the remodelled low mountains of the coast, to the "wild volcanic looking mountains" of the interior height of land, is very marked. Mount Bache, which was determined by the expedition to be 2150 feet high, was "one of the smallest mountains." The larger ones are inaccessible. Those who have been upon the summits of Mount Washington or Katahdin will recognize how well Mr. Lieber's description of the summit of Mount Bache agrees with the physiognomy of the New England alpine summits: —

"A second cause of the irregularity of surface here is to be found in the tremendous power of the frost of a Labrador winter, the influence of the heavy covering of snow, and very probably also the former existence of glaciers, all of which we shall presently take occasion to discuss.

"The effects of frost are manifested in a singularly forcible manner. The entire surface, where it is not too steep to enable debris to collect, is covered with broken masses of rock, cubes of ten feet and less scattered in wildest profusion. Sometimes a patch of moss, the grass and heather of this country, fills up the crevices, but generally we may look down into them far and deep without ever detecting the base upon which the rocks rest, hurled aloft, as they appear, by the hands of Titans. In scaling, in company with Mr. Venable, the summit of Mount Bache, on an occasion intended mainly for taking its altitude barometrically, we enjoyed the finest opportunities for studying this phenomenon. The summit and sides of the mountain present few steep precipices. I speak comparatively only, and in reference exclusively to Northern Labrador. Yet, scattered helter-skelter over all, and piled up in endless number, the whole surface is covered with such loose rocks. The difficulties of locomotion may readily be conceived. In scarcely a single instance did we see the gneiss beds still *in situ*, and in only one or two exceptions some giant wedge seemed to have driven them asunder. Yet none of the blocks were rounded. Attrition of no kind had influenced them to any perceptible extent, neither had atmospheric influences altered the color, hardness and composition of their exteriors; it was simply a wilderness of unchanged blocks of the gray gneiss.

"There was a puzzle. Whence came these broken rocks? There was no higher spot whence they might have fallen. The slight protrusion of the uptilted beds of gneiss *in situ*, to which I have referred, alone seems to have been permitted to remain for the purpose of instructing us. Clearly, that force which had riven its beds asunder, no other than the *frost*, had broken the rest from their foothold and prepared them for removal by another coming into play at a later season; the thawing down-gliding *snow*. Many of the blocks were probably but slightly removed from their original position, perhaps barely turned over or merely forced a little out of place. Yet the effect to the eye of the beholder would be as great as if they had been transported hundreds of miles.

"When we descended from the mountain we crossed over a broad patch of snow, deeply packed, (twenty feet deep,) which clearly taught us how the blocks were moved. In truth, this was a miniature glacier, and a regular moraine was piled up along its edges. It is impossible for us to form any estimate of the amount of snow which may fall per square foot in a winter, but from the fact that such quantities were still remaining late in July, and certainly they never altogether thaw away, we may reasonably infer that during its downward progress, either as snow or water, a tremendous force must be exerted, a force quite sufficient to account for the characteristic surface phenomenon just described." [1]

Contrary to the statement of Sir John Richardson in his "Polar Regions," both the accounts of Parry and the earlier arctic voyagers, and especially C. F. Hall in his "Arctic Researches," prove that on the northern edge of the American continent, and as low down as lat. 62°, and upon land rising between 1000 and 2000 feet above the level of the sea, there is a *mer de glace* of vast extent, discharging glaciers into the sea which present ice-fronts 100 feet high.

Parry, in his second voyage, (p. 12), states that on the north side of Hudson's Straits, after passing by Resolution Island, there "is a smooth part of the land rather higher than that in its neighborhood, and for an extent of one or two miles, completely covered with snow. The snow remains upon it, as Mr. Davidson informed us, the whole summer, as they find the land presenting the same appearance on their return through the Strait in the summer. This circumstance, which has obtained for it the name of 'Terra Nivea' upon the charts, I do not know how to account for, as the height of the land above the level of the sea cannot certainly exceed a thousand feet."

Mr. C. F. Hall, during his residence in Frobisher's Bay, had excellent opportunities of observing during all seasons of the year both ends of the Kingaite range of mountains on 'Meta Incognita' which support this *mer de glace*, which he named the Grinnell Glacier, and which on the coast annually discharges icebergs from its streams. He describes it as being two miles long, starting from a sea of ice which extended many miles N. W. and

[1] *Loc. cit.*, p. 406.

S. E., reaching across the peninsula of Meta Incognita, nearly to the straits which divide Frobisher's Bay from Hudson's Straits. Mr. Hall states that "from the information I had previously gained, and the data furnished me by my Innuit companion, I estimated the Grinnell Glacier to be fully one hundred miles long. At various points on the north side of Frobisher Bay between Bear Sound and the Countess of Warwick's Sound, I made observations by sextant by which I determined that over fifty miles of the glacier was in view from, and southeast of, the President's Seat. A few miles above that point the glacier recedes from the coast and is lost to view by the Everett chain of mountains; and as Sharkey [an Esquimau] said, the *ou-u-e-too* (ice that never melts), extends on *wes-se-too-ad-loo* (far, very far off). He added that there were places along the coast below what I called the President's Seat, where this great glacier discharges itself into the sea, some of it in large icebergs.

"From the sea of ice down to the point where the abutting glacier was quite uniform in its rounding up, it presented the appearance, though in a frozen state, of a mighty rushing torrent. The height of the discharging face of the glacier was 100 feet above the sea."[1]

Given, as stated below, the rise of the Labrador peninsula only 500 feet above its present level, and we must have had during the glacial period most extensive glaciers fed by broad seas of ice resting on the table-lands, reaching above the line of perpetual snow; as only 120 miles northward of Cape Chudleigh we find the snow-line reaching as far down as 1000 feet, or thereabouts, above the sea level. We are inclined to doubt the accuracy of Parry's estimate of the height of these table-lands, as the height of Mount Bache is over 2000 feet, and it just reaches the lowest limit of the snow-line, which in Greenland is 2000 feet above the sea.

Owing to the extensive weathering of the rock, glacial grooves and scratches occur very rarely. I doubt not they will be found abundantly after ascending 500 to 800 feet from the sea level, for below this point the action of the waves and shore-ice has obliterated both striæ and loose drift. We have good evidence that an enormous glacier once filled the great fiord, Hamilton Inlet, which at its mouth is forty miles broad. Peculiar *lunoid furrows* were observed on the northern and southern shores about forty miles apart, which would seem to justify the conclusion, that the glacier was of that breadth where it descended into the sea. The best examples of these lunoid furrows occurred at Indian Harbor on the northern shore of Hamilton Inlet, near the fishing establishment of Mr. Norman. This harbor is a narrow "tickle" or passage, where the Domino quartzites, very smoothly worn and polished, are capped by trap overflows, and run under the water to the depth of thirty feet, forming a polished and smooth bottom to the harbor. The marks occur about twenty-five feet above the water's edge, and below the line of lichens which are kept at a distance by the sea spray.

These crescent shaped depressions which run transversely to the course of the bay, were

[1] J. F. Campbell, who visited this coast in 1864, states in his work entitled "Frost and Fire," that at Indian Island, lat. 53° 30′ "the striæ pointed into Davis' Straits at a height of 400 feet above the sea; at Red Bay, in the Straits of Belle Isle, they aimed N. 45° E. at the sea level."

At Newfoundland, about St. John's, "the striæ which were found were near the coast, and seem to indicate large land-glaciers moving seawards. At St. John's the marks run over the Signal Hill, 540 feet high, from W. and N. 85° W. eastwards; at Harbor Grace, from S. 75° W. down the bay northeastwards; at the head of Conception Bay they fill a large hollow, overrun hills, and point from S. 15° W. northwards. Vast terraces of drift stretch along the base of rounded hills at the head of Conception Bay, at Harbor Grace, and at Old Purlican, near the end of the bay, sixty miles off. At the head of the bay most of this drift seems to have come from the hills. Opposite to granite hills are numerous blocks of granite; opposite to sandstone and slate hills, sandstone and slate boulders abound." — *Frost and Fire*, ii. 1865, p. 240.

from five to fourteen inches broad by three to nine inches long, and about an inch deep vertically in the rock. Their inner, or concave edge, pointed southwest, the bay running in a general S. W. and N. E. direction. They were scattered irregularly over a surface twenty feet square. When several followed in a line, two large ones were often succeeded by a couple one quarter as large, or *vice versa.* Also at Tub Harbor on the southern coast of this bay, similar markings, but less distinct, occurred about the same distance above the sea, and on a similar polished quartzite. These agree precisely with the " lunoid furrows " of Mr. DeLaski, as observed by him in great abundance on Isle au Haut, in Penobscot Bay,— specimens of which he has deposited in the Museum of the Portland Society of Natural History.

These were the only glacial markings I observed. It should be noted that Mr. Jukes, in his " Geology of Newfoundland," states that he never observed any glacial striæ during his explorations on that island. They were observed in abundance by Professor Hind about fifty miles from the mouth of the river Moisie, where occurred " gneiss terraces five in number, the highest being about 1000 feet above the sea, and backed by a stunted birch and spruce-clad mountain, some 800 feet higher still. The sloping sides of these abrupt steps are rounded, polished, and furrowed by glacial action. Cuts half an inch deep, and an inch or more broad, go down slope and over level continuously. Rounded and water-worn boulders are perched here and there on the edge of the uppermost terrace. These strange memorials of the drift begin to be more common."— p. 133.

Fine examples of rounded and embossed rocks occurred at a bay situated a few miles to the westward of Little Mecatina Island. Here the numerous islets of syenites assume a low dome-like shape, whose shores descend to the water's edge by a gentle slope, and are so smooth and polished that one can with difficulty descend them when wet, without slipping.

On the southern coast the eminences all present their longer slopes to the northward, and their lee sides descend seaward and southward in sudden falls and slopes. On the contrary, on the eastern and Atlantic shores the *stoss* or struck sides look westward, and the lee side is on the eastern side of the hills, thus showing that the denuding and abrading agent moved downwards from the top of the water-shed, — that is always nearly parallel to the coast.

About Cape Chudleigh the hills and rocks are shown by Mr. Lieber's drawings to have been rounded and moulded by ice to a height corresponding to that of Mount Bache, as noticed above.

Distribution of Boulders. The whole surface of the country is strewn thickly with boulders. After ascending five or six hundred feet above the level of the sea, and penetrating into the interior, their presence is especially marked. Near the shore they are rarely seen, being covered by vegetation. We must look for them about the edges of ponds and along the banks of the rivers, and especially in raised beaches. I am also inclined to think that their abundance near the coast is greatly lessened by their having been carried off by shore ice into the sea, and there rearranged into submarine beaches.

No loose, single boulders scattered over the surface of the country were seen on the coast from Mecatina to Square Island. They only occurred as stated above, along the courses of rivers, by ponds, and rearranged into beaches. But we first saw them on a hill, estimated roughly to be 1000 feet high, a few miles north of Cape St. Michaels, at Square Island, where they lend a new feature to the landscape. At this level they were strewn sparsely upon the tops of the surrounding hills. One was about fifteen by forty feet in size. A large proportion were well rounded, while others were angular. The greater proportion were of syenite, a few small ones were of greenstone.

Northward of this locality I did not have an opportunity of ascending the mountains above the level of the ancient coast line.

Professor Hind likewise found very few boulders at a distance from the bed of the Moisie, for a distance of fifty miles from its mouth. But on ascending the water-shed, and penetrating farther inland they everywhere grew more numerous. A few miles beyond "Burnt Portage" on this river, "huge blocks of gneiss, twenty feet in diameter, lay in the channel or on the rocks which here and there pierced the sandy tract through which the river flowed; while on the summits of mountains and along the crests of hill ranges they seemed as if they had been dropped like hail. It was not difficult to see that many of these rock fragments were of local origin, but others had travelled far. From an eminence I could discover that they were piled to a great height between hills 300 and 400 feet high, and from the comparatively sharp edges of many, the parent rock could not have been far distant."[1]

Also at Caribou Lake, an expansion of the same river, he states, "the long line of enormous erratics skirting the river looked like Druids' monumental stones; for in many instances they were disposed in such a manner as would almost lead one to suppose they had been placed there by artificial means."— p. 229.

Of this same expedition Mr. Cayley has published an account in the "Quebec Transactions," where we have the statement of this observer that boulders are very thickly strewn over the surface and on the summits of mountains 2214 feet high, and situated one hundred and ten miles from the coast, being near the head waters of the Moisie. "Immense numbers of boulders had for the last few miles strewn the sides of the mountains, in some cases almost seeming to make up the very mountains themselves; there being this difference, that whereas the rock itself *in situ* is granitic, the boulders in every case are of gneiss."[2]

Nowhere did I see on the coast of Labrador any deposits of the original glacial clay, or "unmodified drift." Upon the sea-shore it has been remodelled into a stratified clay, and the boulders it once contained now form terraced beaches. Professor Hind, however, notices the occurrence of "drift clay, capped by sand" in precipitous banks rising seventy feet above the level of the Moisie River, twenty miles from its mouth.

Before giving an account of the marine clays and their fossils, which should naturally come in at this place, I would draw attention to the numerous raised beaches that line this coast.

Raised Beaches. Some of the finest examples of raised beaches and rock-shelves representing ancient coast lines, about 400 feet above the present coast line, are seen in the lowest Silurian rocks on both sides of the Straits of Belle Isle. The following notes and sketches were made while coasting along the northern shore, which rises in high sandstone and gritty bluffs, contrasting in their regular water-worn outlines most strongly with the peculiar swelling curves of the Laurentian gneiss which rise near Bradore, according to Bayfield's measurements, 1200 feet above the sea, — or the jagged, rough and hummocky outlines of the rude syenitic hills, which rise 400 feet above the sea. At Anse au Loup, as

[1] *Loc. cit.*, p. 227. Also, *Quart. Journ. Geol. Soc.*, Jan. 20, 1864, p. 122, On supposed Glacial Drift in the Labrador Peninsula, &c.

[2] Up the River Moisie, *loc. cit.*, N. S., vol. i. p. 88.

seen from one half to one mile from the shore, the land rises on the west side of the bay in three very regular terraces (Fig. 1, A), the lower of which is covered with debris. On the

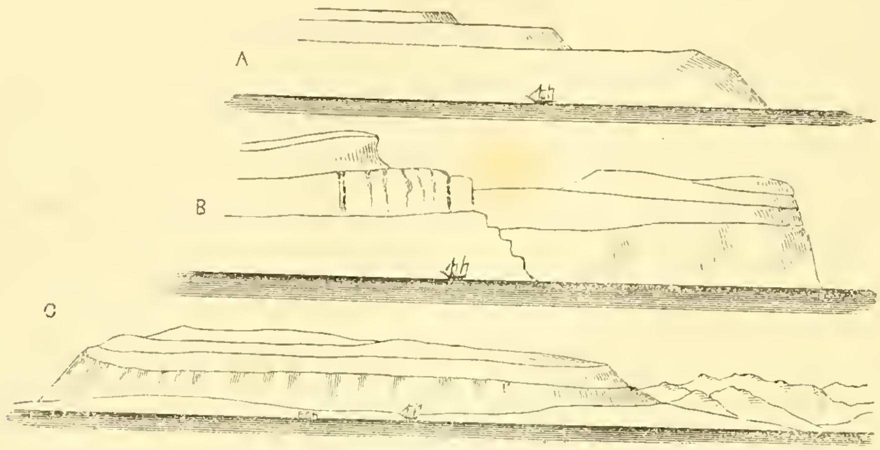

Figure 1.
Terraces at Anse au Loup, (A) (B) and (C) looking eastward at the N. E. end of the Lower Silurian formation.

east side the land is much more irregular, descending in buttressed steeps like the Palisades on the Hudson, though far exceeding them in height. On the east point are five terraces on the N. W. side with heavy buttresses, and beyond four terraces come in sight (Fig. 1, B). The strata here are nearly horizontal, dipping under the Straits at a very slight angle. At the eastward termination of the formation are again seen five very regular terraces (Fig. 1, C) running out in a long low point, beyond which rise the syenite hills. At Blanc Sablon five terraces are very distinctly marked, the second of which is the highest; and there is a beach of huge boulders very regularly packed by the action of the waves, as observed by Admiral Bayfield.

In Chateau Bay and Henley Harbor are some fine examples of ancient sea margins. They occur in recesses in the shore which have been sheltered from the denuding agency of the waves and strong arctic currents, which have swept around this bend in the coast with great power. The most plainly marked example forms the eastern shore of Henley Harbor, being the western shore of Henley Island. This beach, which is 180 feet high above the water level, is composed of three well-marked terraces, which become steeper as we go from the bottom to the top. The upper terrace begins at the base of the basaltic columns capping this island, and is covered at its upper edge with the debris from this mass of trap. The two lower terraces at the northern end of the island present a delta-like expansion facing the northwest. On these terraces, which are destitute of the usual covering of moss and Empetrum, can be most distinctly seen the windrows of pebbles and gravel thrown up by the retreating waves. A continuation of this beach is seen on Castle Island just south.

On the eastern side of the same island is a beach of the same height, but much steeper, as it directly faces the ocean, and more irregular than the one just described, as its surface is broken by jagged masses of syenitic rock which protrude through it, and by large masses of trap which have fallen from the cliffs above.

North of Henley Island is a broad flat beach consisting of two low terraces, on the uppermost of which, and commanding the harbor, are the ruins of an old fort built during the last century. Also on the mainland near the head of the bay are situated in bights in the shore, three low beaches, each composed of two terraces, overgrown with vegetation. They are all apparently of the same height, and correspond in height with that of the second beach or terrace on Henley Island. On the east side of Pitts Arm is another similar beach, and still another at the head of the bay on the west side of the stream emptying into this bay. Upon this latter beach are large boulders often two feet in diameter. Across the bay from Henley Island is a lofty steep beach sloping towards the east, and of the same height.

It is an important fact that the present contour of the coast from the sea level to a height of about 500 feet, also extends to at least fifty fathoms, or 300 feet below the surface of the water. Such we found to be the fact in dredging for a distance of nearly 600 miles along the coast. The jagged nature of the rocky terraces at Strawberry Harbor, so interesting a feature in the coast scenery, extends at least to a depth of 240 feet, a few rods from the shore, as in anchoring with the kedge anchor, it would drop on to a rocky shelf, and then drag and fall twenty fathoms lower on to another syenitic shelf; such a succession of rocky terraces we have no doubt extended much farther below the point sounded by our ship's lead.

Again, dredging was carried on off Henley Harbor on a pebbly bottom 300 feet below the surface which formed the continuation of the same beaches which rose some 200 feet above the sea-level. It follows from this that as both the jagged rocks and submerged beach must have formerly formed a coast line, the land once stood at least 300 feet higher than at present, and it is more than probable. much higher. Such an elevation would have produced the most important modifications of climate, lowering it greatly, bringing the snow line further down towards the coast, and must have led to a great accumulation of the snow and land ice.

At the settlement in Chateau Bay is a remarkably steep beach, which ascends half way up the side of the hill, which is about 500 feet high. It is composed of large boulders very closely packed in layers, without any gravel to fill up the interstices, and slopes to the level of the water at an angle of at least 40°, being the steepest beach I saw on the coast. It consisted of two terraces, the lowest almost precipitous in its descent. This beach, when below the level of the sea, was evidently exposed to the action of the powerful Labrador current which piled these huge water-worn rocks into a compact mass which served to resist the waves, while the coarse gravel and sand were borne rapidly away farther out to sea on to lower levels. It is a general rule that all beaches on this coast with a northerly and easterly exposure to the open sea, are much steeper, and composed of much coarser materials than those in more sheltered situations.

At Domino Harbor are beaches more than 100 feet high, and in sailing up the Sound which lies between the mainland and the numerous islands that line this coast, twelve beaches were seen rising 40 to 150 feet above the level of the sea, and composed of two or three terraces.

In Sloop Harbor, twenty-five miles south of Cape Harrison, is a noble shingly beach nearly 200 feet high on the south side of the harbor, consequently facing the north.

Thomas Bay, which lies about thirty miles south of Hopedale, afforded, along both of its shores for thirty miles from the sea, fine examples of raised beaches, composed for the most part of three terraces. High beaches also occurred at Hopedale. The Mission House and buildings belonging to this Moravian settlement, also rest upon raised gravelly beaches, which afford soil deep enough for gardens and cemeteries.

It is to be regretted that from want of time and proper instruments we were unable to measure the heights of these beaches and their respective terraces. Those given are simply approximative, with the exception of the one noticed as occurring upon Henley Island. The mass of basalt was rudely measured by Lieut. Baddeley, and estimated to be 255 feet high. The terraces rise to the base of the pillars, which he estimated to be 180 feet above the sea.

I believe it will ultimately be found that all these beaches rise above the present level of the sea at uniform heights, and will be found generally to agree in this respect with similar beaches in the St. Lawrence River and the coast of the British Colonies and New England, after making due allowances for local oscillations of the land. At Chateau Bay it could easily be seen that all the terraces composing the different beaches were of the same height; and, so far as memory would show, in the absence of actual measurement, all those beaches observed farther northward presented terraces which very generally corresponded in height with those of Chateau Bay.

I am informed by Captain Ichabod Handy of New Bedford, Mass., who has spent several years in Hudson's Bay engaged in the whale fishery, who is a close observer, and has coasted in a whale-boat the whole shore from Nain to Resolution Island in lat. 62°, that there are several very high raised beaches near Hebron, and also near Nain, one of which he roughly estimated to be 300 feet high. He observed that the beaches north of Nain increased in height. There were also beaches on Button Island. He noticed one on Resolution Island, about 200 feet high, which was composed of three terraces. On the Lower or East Savage Island he described to me a plain of soft clay elevated fifty feet above the sea, into which "he sank knee-deep," and perceived in it numerous "clams and mussels," and also the skeleton of a whale, the "boar-head" whale, (*Balaena boöps*) stranded upon the surface. This ancient sea bottom was flanked by a raised beach from thirty to forty feet in height.

At Sir Thomas Roe's Welcome, he describes the beaches as being higher than any observed southwards, and he also noticed clay-banks, containing shells, raised above the present level of the sea.

Prof. Hind has noticed some remarkable beaches far in the interior of the southern part of the Peninsula, and at a great height above the present level of the sea. Though this author does not refer to their rearrangement by the currents and waves of the sea, his description of the immense deposits of rounded and water-worn boulders, agrees precisely with similar raised beaches both upon, and a mile back from, the coast, observed by myself, where they are covered by moss and Empetrum, or stunted spruces. At "Burnt Portage," upon the river Moisie, one hundred miles from its mouth, and 1857 feet above the level of the sea, this author describes a "hill of boulders or erratics, all water-worn and smooth, without moss or lichen upon them, and piled two or three deep, and, for aught you know, twenty deep." . . . "The well-worn masses of all sizes, from one foot to twenty feet in diameter, and from one ton to 10,000 tons in weight, are washed clean." . . . "I could without difficulty see three tiers of these 'travelled rocks,' and in the crevices the charred roots of trees which had grown in the mosses and lichens which formerly clothed them."

Another feature of great interest in this connection are the rocky terraces or steps which have been hewn out of the solid rocks along the coast for a height of 500 feet above the present level of the sea, and mark the oscillations of the old coast line; and, as there occur in the interior of the country 1000 feet above the present coast line, similar lines of erosion, they present the best evidence we have, to determine how far above its present level the glacial sea stood. These rock terraces could only have been formed so fully as seen here during a vast period, and the ice-foot of Dr. Kane, to which their formation is probably due, must have remained on the shore during the entire year. Fine examples of similar terraces are described and figured in Kane's "Explorations," Vol. ii. p. 81. At various points along the coast the joint action of frost, the waves, and floating ice, can even now be seen building up these steps in the slopes of trap and syenitic rocks, by taking advantage of the jointure and cleavage planes which cross at nearly right angles. At Strawberry Harbor the syenitic rocks have broken off into huge cubical blocks of many tons' weight. The rock abounds in cracks and fissures, into which the ice has entered wedge-like, and burst them asunder, while the fragments have been borne away by shore-ice. Thus for a height of 500 feet the shore consists of a series of steps ten to thirty feet high, forming broad shelves on which the sea-birds build, and where a little vegetation lodges. Where the shore consists of trap rocks, as at Domino Harbor and Tub Island, the steps are much smaller and more numerous. At Domino there are regular steps in the quartzites, which lend a very peculiar feature to the shores of the harbor, as at a little distance the rocky slopes descending by hundreds of steps to the water, appear like a lofty beach of boulders. At Sloop Harbor these rocky steps are of vast extent, their tops shelving inland, and in profile the rocky promontory presents a strange serrated outline when viewed from the sea. The lofty sugar-loaf syenitic island a few miles south

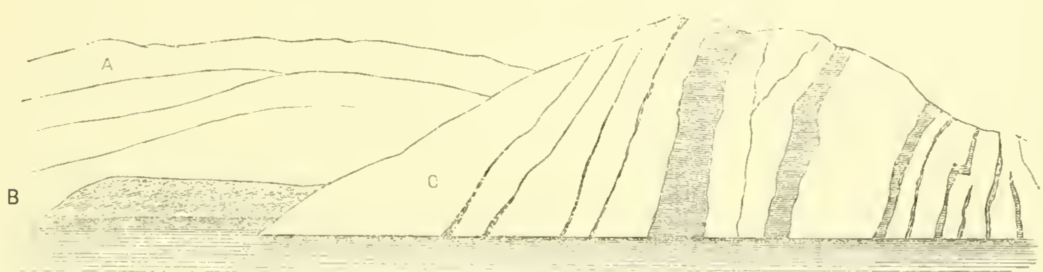

Figure 3.
View just north of Sloop Harbor, Kyueartarbuck Bay; (A) gneiss terraces, 500 to 800 feet high; (B) raised beach at the head of a small bay; (C) a headland of Domino quartzite (?) intersected by trap dykes.

of Hopedale, noticed previously, and which is 700 feet high, has its surface divided into four terraces of rock, which reach two-thirds of the distance up its sides from the water,

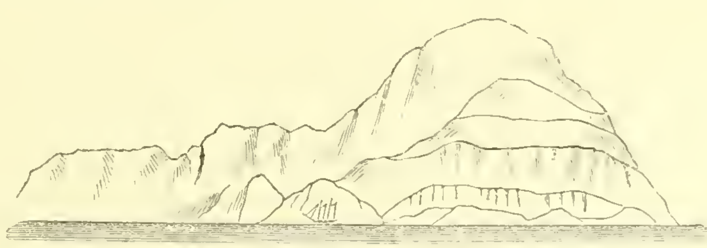

Figure 2.
Rock terraces on a conical promontory near Hopedale, Labrador.

thus affording a means of estimating the different heights at which the land paused in its oscillations upwards. We must again refer to Mr. Hind's work for an account of similar rocky terraces in the interior of the Peninsula. Near the "Lake where the land lies," he describes the gneiss hills as rising in "gigantic terraces." He likewise speaks of "gneiss terraces five in number, the highest being about 1000 feet above the sea," and he states that the sloping sides of these abrupt steps are rounded, polished, and furrowed by glacial action.[1]

Mr. Cayley has described them also quite fully: "We now made the fifth portage, [fifty miles from the mouth of the river, and 370 feet above the level of the sea,] where we first met with some curious natural steps or terraces, which were continually repeated on our march. They were usually five or six in number, averaging three or four feet in height; the distances between each rather irregular, just affording room enough to take two or three paces, and their surfaces presenting the appearance of having been artificially constructed. They were of the common dark hornblendic gneiss, and ran in a general northeast and southwest direction."[2]

No glacial striæ upon these terraces were observed near the shore. It is evident that this process of terracing the crystalline rocks by frosts and shore-ice began during the glacial epoch. At present we must assume that the striæ found by Professor Hind upon these rocky steps far inland were graven by angular stones frozen into the bottoms of glaciers, for we find no such marks at present upon those now upon the coast, which shows how insufficient is the action of floating shore, or floe-ice, or grounded bergs even, in striating so regularly these hard crystalline rocks.

We saw a good example of rocks polished by the ice and waves at Gore Island Harbor, a point westward of Little Mecatina Island. On the faces of several cliffs forming perpendicular walls facing a narrow passage into which the waves rushed with great force in the calmest days, the sea-wall was smoothly polished and water-worn for ten feet above its shore-line, while above, the face of the cliff was roughened by the action of frost.

Upon this coast, which during the summer of 1864 was lined with a belt of floe-ice and bergs probably two hundred miles broad, and which extended from the Gulf of the St. Lawrence at Belles Amours to the Arctic seas, this immense body of floating ice seemed *directly* to produce but little alteration in its physical features. If we were to ascribe the grooving and polishing of rocks to the action of floating ice-floes and bergs, how is it that the present shores far above (500 feet), and at least 250 feet below the water-line, are often jagged and angular, though constantly stopping the course of masses of ice impelled four to six miles an hour by the joint action of tides, currents and winds? No boulders, or gravel, or mud were seen upon any of the bergs or masses of shore-ice. They had dropped all burdens of this nature nearer their points of detachment in the high Arctic regions. The bergs all bore evidence of having been repeatedly overturned as they were borne along in the current. The floe-ice was hummocky, which is a strong proof of its having come from open straits in the polar regions, the masses looking as if having been frozen and refrozen, jammed together, and then piled atop of each other by currents and winds long before appearing upon this coast; while the bergs exhibited old water-lines presenting different angles to the present water-level. The only discoloration noticed was probably caused by seals resting upon and soiling the surface. One boulder was noticed by a member of the party resting upon an iceberg off Cape Harrison in August.

This huge area of floating ice, embracing so many thousands of square miles, was of

[1] *Loc. cit.*, p. 133.

[2] Up the River Moisie, *loc. cit.*, p. 82.

greater extent, and remained longer upon the coast, in 1864, than for forty years previous. It was not only pressed upon the coast by the normal action of the Labrador and Greenland currents which, in consequence of the rotatory motion of the earth, tended to force the ice in a southwesterly direction, but the presence of the ice caused the constant passage of cooler currents of air from the sea over the ice upon the heated land, giving rise during the present season to a constant succession of northeasterly winds from March until early in August, which farther served to crowd the ice into every harbor and recess upon the coast. It was the universal complaint of the inhabitants that the easterly winds were more prevalent, and the ice "held" later in the harbors this year than for many seasons previous. Thus the fisheries were nearly a failure, and vegetation greatly retarded in its development. But so far as polishing and striating the rocks, depositing drift material and thus modifying the contour of the surface of the present coast, this modern mass of bergs and floating ice effected comparatively little. Single icebergs, when small enough, entered the harbors, and there stranding, soon pounded to pieces upon the rocks, melted, and disappeared. From Cape Harrison in lat. 55° to Caribou Island was an interrupted line of bergs stranded in eighty to one hundred or more fathoms, often miles apart, while others passed to the seaward down by the eastern coast of Newfoundland, or through the Straits of Belle Isle.

Secular Rise of the Land. From all the indications noticed casually by us, such as the position of beaches apparently very recently raised above the sea-level, so as to be just beyond the reach of the waves, the land is slowly gaining on the sea. The Rev. C. C. Carpenter, missionary at Caribou Island, in the Straits of Belle Isle, also informs me that this is his impression gained both from his observations and information given by the settlers. To this last source Mr. J. F. Campbell is indebted for the statement in his "Frost and Fire," that the coast of Labrador is slowly rising.

River Terrace Period. Owing to the great denudation of all drift material, and the hilly character of the country, we find no broad terraced river valleys, such as characterize more temperate regions. On the contrary, the rivers are a succession of ponds, connected by rapids, where the stream plunges from one rocky terrace to the next one below, taking the direction of natural ravines. Though the volume of these rivers during the Terrace epoch, or period of great rivers, may have been greater than now, as evidenced by a few small terraces upon their banks, we have no evidence that they ran in much wider channels than at present, owing to the great height of their banks.

Leda Clays.

Their occurrence in Labrador. — At the mouth of Salmon River, a small stream flowing into the Straits of Belle Isle three miles east of the mouth of the Esquimaux River, occurred a clay-bank about ten feet high, and situated just above high-water mark, which was dark blue and free from boulders. It contained in abundance *Aporrhais occidentalis, Serripes grönlandicam, and Cardium Hayesii.*

This deposit of clay is of more recent age than the deposits noticed below, as it was a few feet higher, and situated more inland. It undoubtedly rests upon the lower fossiliferous gravel beds, though I did not see the point of contact.

The most important deposits occurred at Caribou Island at the mouth of the Straits of Belle Isle, at Pitts Arm in Chateau Bay, and at Hopedale. They consisted of sandy clays and a coarse gravel found between tide marks, and extending beneath the water. Should the present banks now lying off the coast be raised and exposed to view, we would have an identical deposit. All the stones and pebbles of this ancient sea-bottom, finely exposed at Hopedale, are covered with nullipores and polyzoa; the Mya truncata still remains perpendicular in its holes, and the most delicate shells with their epidermis still on, are unbroken, and their valves often united by the ligament. The delicate Myriozoum has preserved its fine markings nearly as perfectly as in specimens dredged at the present day, and the cases of the delicate Spiochætopterus are still preserved. It is evident that this deposit has slowly and almost imperceptibly risen some 400 or 500 feet without any paroxysmal movement of the continent over an extent of coast some 600 miles in length.

This rise of the Labrador peninsula must have accompanied the rise of the Polar Regions, including Arctic America and Greenland, and in fact all the land lying in the northern hemisphere. Many facts in the distribution of fossils in these glacial beds, and the present relations of these beds to deposits above and beneath them, tend to prove that the glacial epoch occurred simultaneously over all the Arctic Regions and the northern temperate zone, and that the submergence and subsequent rise of the continental masses and outlying islands, were synchronous in both hemispheres. Professor Haughton has summed up the evidence of such a rise from raised beaches and ancient sea-bottoms, in the American Arctic Archipelago.[1] The researches of Dr. Kane in the extreme north of Greenland enabled him "to assert positively the interesting fact of a secular elevation [480 feet] of the crust commencing at some as yet undetermined point north of 76°, and continuing to the Great Glacier and the high northern latitudes of Grinnell Land." Vol. ii. p. 81.

We need not here allude to the similar oscillations in Northern and Central Europe to still greater heights above the present level of the ocean.

At various points along the coast from Caribou Island, where they were abundant, to Hopedale, occurred in the drift gravel beds associated with the fossils, numerous pebbles and small boulders of a light silicious bedded limestone, which contained numerous Silurian fossils. Lieber mentions finding pieces of limestone on the shore of Aulezavik Island. There can be little doubt that these boulders were transported on ice from the Silurian basins in the Arctic regions on the west side of Baffin's Bay. Perhaps their origin may by future observers be traced to the Silurian limestones found at the head of Frobisher's Bay, by Hall. Such fragments are not now to be seen on the floe-ice coming down from the north.

A large proportion of the species mentioned in the following lists occurred in great abundance, and in a good state of preservation, so that they could be compared very satisfactorily with recent specimens dredged upon the coast. Most of the species, after careful and repeated comparisons with the recent examples, did not present any appreciable differences. In a few instances there were characters found by which the fossils could be distinguished from the recent shells of the same species, and those I have carefully enumerated.

[1] "McClure found shells of the *Cyprina islandica*, at the summit of the Coxcomb Range, in Baring Island, at an elevation of 500 feet above the sea level; Captain Parry, also, has recorded the occurrence of *Venus* (probably *Cyprina islandica*) on Byam Martin's Island; and in the recent voyage of the "Fox," Dr. Walker, the surgeon of the expedition, found the following sub-fossil shells at Port Kennedy, at elevations of from 100 to 500 feet: *Saxicava rugosa*, *Tellina proxima*, *Astarte arctica* (borealis), *Mya uddevallensis*, *Mya truncata*, *Cardium sp.*, *Buccinum undatum*, *Acmea testudinalis*, *Balanus uddevallensis*." —*Appendix to McClintock's Narrative.* Amer. edit. p. 370.

Nullipora polymorpha Linn. This plant occurred abundantly at Caribou Island. At Hopedale it was profusely abundant, growing in large free masses or encrusting shells and stones.

Euryechinus dröbachiensis Verrill. (*Toxopneustes dröbachiensis* A. Agassiz. *Echinus granularis* Say.) Fragments of the shells and numerous spines occurred abundantly at Caribou Island and Hopedale.

Lepralia Belli Dawson. Encrusting pebbles at Hopedale. One colony also on a shell. The young cells were large, with crowded and sometimes perforate, granulated conical ovicells. The avicularia are situated either in front of the opening, or crowded to one side, and are two in number. Both old and young correspond precisely with a specimen received from Dr. Dawson.

Lepralia pertusa Thompson. This species occurred on the shells of *Buccinum cretaceum.* It agrees well with the large, oblong and coarsely punctate recent specimens. It is well figured by Dawson in the *Canadian Naturalist and Geologist,* Feb. 1859, p. 15, fig. 16.

Lepralia ciliata Johnst. This form also occurred frequently with the preceding. The cells are convex, the avicularia are present, projecting over the aperture. The surface is punctate.

Celleporaria surcularis Packard, Can. Nat. Dec. 1863, p. 410. Occurred frequently on Lamellibranch shells in large and thick masses at Caribou Island and Hopedale.

Myriozoum subgracile D'Orbigny. (*Millepora truncata* Fabr., Faun. Grœnl.) Fragments of the stems of this graceful species occurred abundantly at both localities.

Hypothyris psittacea King. Perfect valves were found at Caribou Island, and others were given me which were reported to have been found three miles from the mouth of the Esquimaux River. Other shells, such as a *Cardium* and *Cardita borealis,* also came from the same place, showing that they had been washed out of a drift deposit on the river. This species was abundant at Hopedale, where the valves adhered by their ligament.

Pecten islandicus Linn. This was not common. Several ponderous valves, larger than I have seen elsewhere had the ribs united into groups of two or three, separated by sulci of equal width; but in young and fragile subjects the ribs were equally distributed, and differed in no respect from the living young, or from those of the same age from the drift clays of Maine and New Brunswick.

Yoldia myalis Stimps. A specimen of *Yoldia arctica,* received from Dr. Lütken, approaches *Y. myalis* more than *Y. sapotilla.* It is, however, longer, and the lunule is not so short and deep as in *Y. myalis.* One valve. Hopedale.

Leda minuta Möll. (*Arca minuta* Fabr., Faun. Grœnl.) Caribou Island, rare. Common at Hopedale.

Modiolaria discrepans Möll. One broken valve. Hopedale.

Mytilus edulis Linn. Fragments of large valves were abundant, but young shells were uncommon.

Cardium Hayesii Stimps. Proc. Acad. Nat. Sc. Philad. p. 581, 1862. This species occurred both at Hopedale and Caribou Island.

Serripes grönlandicus (Chemn.) Beck. Caribou Island, frequent. Chateau Bay.

Astarte Banksii Leach, Zoöl. Beechy's Voyage (*A. Warhami* Hancock, Ann. Mag. Nat. Hist., vol. xviii., 1846, p. 336, pl. v., figs. 15, 16. *A. Richardsoni* Reeve, Last of the Arctic Voyagers, ii. App. *A. fabula* Reeve. l. c.; *A. Laurentiana* Lyell; *A. compressa* Daws., — not of European authors.) A fine series of specimens, recent and fossil, from Labrador, and fossil from Maine and the river St. Lawrence, has convinced me that the numerous variations of form which this species assumes, are of local origin arising from differences in habitat or age. Among a number of *A. Laurentiana* Lyell, received from Montreal through the kindness of Dr. Dawson, are some thinner and more finely striated than usual, but I have recent specimens and also fossils from Labrador agreeing with them. The species varies in the length of the shell, and the form of the posterior end, but the shape of the anterior end, the sulci and the hinge characters, are in all the varieties very constant.

Very elongated forms are like *A. Warhami* Hancock, which we would consider as a synonym of this species. The varieties *A. Richardsoni* and *A. fabula* have occurred in the same locality, at Dumplin Harbor at the mouth of Sandwich Bay, Labrador, where I have dredged them alive.

Astarte striata Gray. One specimen from Hopedale. It did not differ from drift shells found at Brunswick, Maine. This shell, as it occurs fossil, is thicker, more ponderous, more equilaterally triangular; the beaks are directed more anteriorly, the teeth are much larger, and the lunule broader and shorter, than in *A. Banksii*.

Astarte compressa Linn. (*A. elliptica* Brown.) Common in all the beds, but not so abundant as *A. Banksii*.

Cardita borealis Conr. Very abundant with the preceding.

Macoma sabulosa Mörch. (*Tellina proxima* Brown.) Of frequent occurrence.

Cyrtodaria siliqua Daudin. Several valves at Caribou Island.

Panopæa norvegica Sprengel. A perfect valve of this shell occurred at Caribou Island.

Mya truncata Linn. Both the short and common elongated varieties of this species occurred especially at Hopedale in great profusion.

Saxicava arctica Desh. Large valves occurred in great profusion in all these beds.

Chiton marmoreus O. Fabr. Several valves were found at Hopedale.

Tectura testudinalis Gray. One specimen occurred, encrusted with Nullipora.

Lepeca cæca Möll. (*P. candida* Couth.; *P. cerea* Möller, Reeve); frequent.

Cemoria noachina Leach. (*Diadora noachina* Gray.) Frequent.

Margarita cinerea Couth. One specimen. Hopedale.

Margarita varicosa Mighl. et Adams. Frequent at Hopedale and Caribou Island.

Turritella erosa Couth. As numerous in proportion to the succeeding species as at present on the coast.

Turritella reticulata Mighl. et Adams. (*T. lactea* Möll.) Profusely abundant in both places.

urritella acicula Stimps. One specimen. Caribou Island.

Aporrhais occidentalis Beck. Several. Caribou Island.

Lunatia grönlandica Möll. Frequent.

Natica clausa Sowb. Frequent.

Admete viridula Stimps. At Caribou Island.

Bela robusta n. sp. [Plate vii., fig. 12.] No specimens of this species occurred at Caribou Island associated with the other species; it seems quite rare, and has not occurred in a living state. Though very distinct from any of the other species, it might be mistaken for a very much shortened and thickened *B. americana*. It is much shorter and broader than *B. americana*; the whorls are five in number, angulated, giving the shell a well-marked turretted form; the fourth whorl is one half to two thirds as long as the first, which is unusually large in proportion to the rest of the shell. The aperture is broad, regularly ovate; canal, long, narrow, oblique, and not gradually widening towards the aperture. It has much fewer ribs than *B. americana*, there being thirteen on the lower whorl, where in *B. americana* are eighteen. Length .18; breadth .11 inch.

Bela americana Packard. (*Fusus turriculus* Gould, Invert. Mass. *Bela scalaris* Packard, Can. Nat. and Geol. 1863, — not of Möll., Index Mollusc. Grönl.) *Variety.* [Plate vii., fig. 11.] One specimen occurred fossil at Caribou Island which differed in no respect from a recent specimen dredged in 15–30 fathoms at Square Island, which will be further noticed below.

Bela exarata Möll. (*Defrancia exarata* Möll., Index Mollusc. Grönl.; *Pleurotoma rugulatus* "Möll." Reeve, Icon. Conch. f. 345.) Caribou Island. Common.

Bela Woodiana Möll. (*Pleurotoma harpularia* Couth., Bost. Journ. ii., p. 183. *Pleurotoma leucostoma* Reeve, Icon. Conch. f. 278.) Caribou Island. The most common species of the genus in these deposits, though very rarely found living by us; it is of large size and much eroded.

Bela decussata (Couth.) It occurred very rarely at Caribou Island.

Bela pyramidalis (Ström.) (*Pleurotoma rufa* Couth.) Not common; at Hopedale and Caribou Island.

Bela violacea Mighl. et Adams. (*Defrancia cylindracea* Möll. Ind. Moll. Grönl.; *Pleurotoma grönlandica* Reeve, l. c. fig. 343.) Of common occurrence at Caribou Island.

Buccinum glaciale Linn. Caribou Island, an imperfect specimen.

Buccinum grönlandicum Hancock. Annals and Mag. Nat. Hist. xviii., p. 329, pl. v., figs. 8, 9, 1846. [Plate vii., fig. 5 *b*.] Pitt's Arm, head of Chateau Bay; one specimen, with the outer coating of shell worn off.

Buccinum tenue Gray. (*Buccinum scalariforme* Beck, Stimps., Can. Nat., Oct. 1865, p. 14.) One specimen occurred at Caribou Island, wanting the lip and spire, but showing well the abbreviated longitudinal waves characteristic of the species.

Buccinum undulatum Möll. (*B. undatum* Greene, Gould, Dawson; *B. labradorense* Reeve, Packard, Can. Nat. viii. p. 416, 1863.)

Buccinum cretaceum Reeve, Icon. Conch, Packard, Can. Nat. viii., p. 417, pl. ii., fig. 6, 1863. [Plate vii., fig. 7.] This interesting species, now found not uncommonly on the coast of Labrador, also occurs fossil not unfrequently at Caribou Island. It differs in no respect from living forms.

Fusus (*Neptunea*) *tornatus* Gould. Rarely found fossil at Caribou Island, and in the blue clay at the mouth of Salmon River.

Fusus (*Neptunea*) *labradorensis* n. sp. [Plate vii., fig. 8.] Shell fusiform; whorls moderately convex, sutures deeply impressed, the upper ones somewhat flattened, spire elongated, acute, lower whorl ventricose, covered with rather coarse revolving striæ. On the lower whorl are twenty nearly straight, coarse, flattened folds, which on the succeeding whorls run the entire length of each whorl. Aperture ovate, columella concave, smooth; canal moderately long, oblique, slightly tortuous, spire a little longer than the shell. Length, one inch; breadth .48 inch. One specimen at Caribou Island. It differs from *Fusus pullus* Reeve (fig. 89.) in being apparently a much thicker shell, in the longer canal, and in the more ventricose body of the shell, with the coarser revolving lines.

Fusus tortuosus Reeve, Belcher's last of the Arctic Voyagers, ii., p. 394, pl. 32, fig. 5. Our specimens differ from the description, in the absence of the long tortuous canal which gives the species its name. The fossils have the same convexity of the whorls, which are covered by similar revolving striæ; but the first whorl is less contracted at the origin of the canal, and the canal itself is from half to two thirds the length of the first whorl, while in *F. tortuosus* the canal nearly equals the length of the whorl. In this respect it approaches *Fusus pygmæus* Gould, from which it is distinguished by its size, the greater convexity of its whorls, and the deeply impressed revolving lines.

In several specimens of *Fusus islandicus* from Eastport, Me., I find that the length and tortuosity of the canal is subject to considerable variation. Of two specimens collected together at low-water mark, one had a short and nearly straight canal, while in the other it was much elongated and twisted. Hence before separating our fossil species from *F. tortuosus* Reeve, more of the recent shells are desirable.

This was a frequent shell in the gravel deposit on Caribou Island, and large specimens measured nearly three inches in length.

Trichotropis borealis Sowb. et Brod. Not uncommon at Hopedale and Caribou Island.

Spirorbis glomerata Müll. Occurred as usual on shells at Caribou Island.

S. vitrea Stimps. Only young and flattened specimens occurred.

Spiochætopterus typus Sars, Fauna littoralis, ii. Fragments of tubes belonging apparently to this worm were found fossil at Caribou Island.

Balanus porcatus Da Costa. Numerous fragments occurred at Caribou Island and Hopedale.

In the above list occur several forms of great interest which have not been found fossil elsewhere, or in no such profusion, and seem to be perhaps characteristic of this fauna and to have had their metropolis either in this area or in Arctic America, in contradistinction from Arctic Europe. Such are

Cardita borealis,	*Aporrhais occidentalis,*	*Bela americana,*
Astarte Banksii,	*Admete viridula,*	*Fusus tortuosus,*
Margarita varicosa,	*Bela exarata,*	*Fusus labradorensis,*
Turritella reticulata,	*Bela Woodiana,*	*Buccinum undulatum,*
Turritella erosa,	*Bela robusta,*	*Buccinum cretaceum.*

From this list the polyzoa are excluded, since no species are recorded from Greenland, except by Otho Fabricius in the Fauna Grönlandica.

Upon comparing this list with that of the species comprised in the present fauna, as published in the latter part of this paper, we can observe how similar are the two faunæ, and how persistently the characters of the earlier of the two have survived the important changes this region has undergone since the glacial epoch. We have here the present Syrtensian fauna in its purity, without the intermixture of the few southern forms, that have subsequently encroached upon its limits. We shall below show where it shaded almost imperceptibly into the Acadian fauna, its nearest southern neighbor; but now we have to determine its most northern limits.

Fortunately Möller, in his "Index Molluscorum Grönlandiæ," and Rink,[1] have noticed the few fossils which have occurred in the Quaternary clays of Southern Greenland, a list of which is here given.

[1] Udsigt over Nordgrönlands Geognosi af H. Rink. *Viden. Selsk. Skrifter, Kjöbenhavn*, 1853, p. 96. The species were identified by Dr. O. A. L. Mörch.

Pecten islandicus,	*Cardium islandicum,*	*Tellina calcarea,*
Leda minuta,	*Cryptodon flexuosus,*	*Tellina fragilis (grönlandica),*
Mytilus edulis,	*Cyrtodaria siliqua,*	*Natica clausa* B. & S.,
Modiolaria discors,	*Mya truncata,*	*Littorina grönlandica,*
Astarte semisulcata Leach,	*Mya arenaria,*	*Fusus despectus* Linn,
Astarte corrugata Brown,	*Panopæa norvegica,*	*Margarita glauca,*
Cardium (Aphrodite) grönlandicum,	*Saxicava arctica,*	*Fusus gracilis* Da Costa.

The Leda Clays of Anticosti. In their expedition to this island, referred to in the "Canadian Naturalist," Messrs. Hyatt, Verrill, and Shaler found at the southwest point of Anticosti a deposit of blue drift clay containing *Saxicava arctica.* The shells occurred at ten feet above high-water mark, while fragments were found fifteen feet higher. This was the only fossil noticed.

The Leda Clays of New Brunswick. An interesting collection of invertebrates, received from Messrs. G. F. Mathew and C. F. Hartt of St. John, N. B., enables us to add to our lists several new forms of very considerable importance. They mostly occurred in red clay resulting from the denudation of the Devonian and Triassic deposits about the Bay of Fundy.

Ophiura Sarsii Lütken. St. John. This species has been determined by Dr. Stimpson.
Euryechinus dröbachiensis Verrill. Lawlor's Lake.
Lepralia hyalina Johnst. " "
Membranipora pilosa Johnst. " "
Cellepora pumicosa Ellis. " "
Pecten islandicus Linn. Lawlor's Lake. St. John, R. R. Depot.
P. tenuistriatus Mighl. (*P. magellanicus* Lamk.) St. John.
Leda buccata Steentp. (*L. Jacksoni* Gould.) Lawlor's Lake. Duck Cove.
Leda truncata Brown. (*Leda portlandica.*) Abundant. Lawlor's Lake. Duck Cove.
Nucula antiqua Mighl. Negrotown Point.
Mytilus edulis Linn. Lawlor's Lake. St. John.
Cardium islandicum Chemn. " "
C. pinnulatum Conr. Abundant. Lawlor's Lake. St. John.
Serripes grönlandica Beck. St. John. I have not seen the specimens of this species.
Astarte Banksii Leach. Black Point.
Macoma sabulosa Sprengel. St. John. Manarragonis.
M. grönlandica Stimps. Lawlor's Lake. St. John.
Mya arenaria Linn. " " " "
M. truncata Linn. Manarragonis. My specimens are too fragmentary to decide to which variety they belong.
Saxicava rugosa Linn. Lawlor's Lake. St. Andrews. Manarragonis.
Natica clausa Sowb. " " St. John.
Lacuna neritoïdes. Lancaster.
Balanus hameri Ascanius. Lawlor's Lake. Bathurst.
B. porcatus Da Costa. " " St. John.
Cancer sp.

There were besides well-preserved fragments of a fucus and a brown alga with a broad thin frond.

The Leda Clays of New England. General Features of drift action in Maine. Before describing the beds in which fossils are found in Maine, let us take a glance at the topographical features of this district and the relative distribution of the different members of the materials composing the superficial deposits of the State. This we are enabled to do from personal observation made in several excursions along the sea-board and into the interior through the wild lands, and from data given by C. H. Hitchcock in the "Reports of the Geological Survey of Maine," 1862–3.

The coast of Maine, while running in a general N. N. E. direction, thus corresponding to the general trend of the continent consequent on the upheaval of the Appalachian Mountain chain, forms part of a great indentation in the Eastern Atlantic coast, lying between Cape Cod and Cape Sable, Nova Scotia. This direction of the coast line, there is every reason to think, was determined long before the glacial period. Into this broad bay the river systems empty their waters, flowing, from Cape Ann to Casco Bay, in a general N. W. and S. E. direction. The Merrimac, after leaving the limits of the State of New Hampshire, flows in a northeast direction to the sea, but its general course seaward is southeasterly. Going farther north, the Saco flows in a very direct southeast course. This is the general course of the Androscoggin River. At this point the direction of the rivers changes. The Kennebec flows due south from its head-waters, Moosehead Lake. The Penobscot takes its rise in the highlands isolated from the Alleghany range, and flows in a direction slightly west of south. The S. E. direction is again resumed when we come to the St. Croix and St. John rivers, for their course lies nearly parallel to that of the Androscoggin. While assuming this general direction west of north, the *mouths* of the rivers of Maine within a few miles of the sea change their course almost at right angles, and assume the N. N. E. and S. S. W. course of the fiords. This is quite an important point in the consideration of the N. E. and N. W. course of the drift striæ, and explains, it would seem quite satisfactorily, the remarkable differences in the course of the striæ along the coast as distinguished from those in the interior.

In this connection let us advert briefly to the distribution of the lakes in Maine. They are by no means scattered irregularly over the surface of the State. The general direction of their longer axes is N. W. and S. E.; thus they run nearly at right angles to the course of the fiords or deep bays. We can also perceive an arrangement into two series: one, the inner, higher above the sea than the other, and resting on the great water-shed of the State, from which flow streams running north and south. If we draw a line through Lakes Umbagog, Moosehead, Chesuncook and the numerous lakes (Chamberlain, Webster, Telos, and Churchill) which form the head-waters of the Alleguash on the one hand, and the Penobscot on the other, and also the Schoodic Lakes and the broad, lake-like expansions of St. John River, we shall describe a great curve assumed by this water-shed, and which lies parallel to the sea-coast. A lower tier of lakes, inferior in size, as they are of less importance in the system of drainage, is also parallel to the coast, and situated just above the first or upper falls of our great rivers, or at the head of tidal waters; — these are Lake Sebago, the large lakes lying just above Augusta and Bangor, and the Grand Lakes on the eastern border of the State. At the time of the deposition of the upland clays, and during the later period of submergence when the *osars* and sea-beaches were laid down in the interior of the State, and deep bays and fiords occupied the beds of the present lakes, we see that the course of those fiords were at nearly right angles to the direction assumed by those of the present coast line. This applies to each of the two interior coast lines. It is also evident that the middle coast line is more complete, the descent more abrupt at a given point, and consequently it is probable that the sea stood for a great length of time at this level. It is doubtful whether the inner series of lakes lying on the water-shed were ever deep fiords, as we have no evidence from fossils that the sea rose over 500 feet above its present level.

There is a special connection between the distribution of the three varieties of clays in the State, which present such different lithological and palæontological, or in the case of one, want of palæontological characters.

As we shall see below, the lowest horizon of life occurs in beds exposed only near high-tide mark on the coast, and consisting of an unusually tough clay filled with boulders overlaid by a great thickness of clay, which gradually becomes lighter in its character as we ascend to the upper layers. This is the earlier boulder clay. Next we have lighter brick-yard clays with their peculiar horizon of life, which are spread over the lowlands between a line about 25 feet above the high-tide mark, and the middle coast line from twenty to seventy-five miles in the interior and rising 200 feet above high-tide mark. Again, between this middle coast line and the top of the water-shed or interior line of coast and the bases of the mountains, occur the moraine clays or unmodified drift, though all these three varieties of clays evidently graduate into each other. In this inland area there is a greater proportion of rock surface exposed, and a far greater abundance of boulders, arranged in clearly marked trains, than upon the coast. In this highland region occur the marks of ancient glaciers, left in these trains of boulders, which were undoubtedly lateral moraines, and in the terminal moraines in the form of tumuli and especially rounded hillocks of peculiar shape, consisting wholly of gravel, which have been rounded by the subsequent action of the sea, and farther modified by the action of the broad rivers of the Terrace Epoch.

While the general direction of the drift or glacial striæ in the State is northwesterly, there are two other courses, a general north and south one, and more rarely a northeasterly course. In analyzing the directions of these striæ, as given by Mr. C. H. Hitchcock in the first "Report on the Geology of Maine," 1862, for seventy-seven localities, to which we would add three localities, Brunswick, Falmouth, and Lewiston, making eighty in all, we find that one of the number alone runs north and south, while sixty-two of the number run west of north; and seventeen, or less than one-fourth, run east of north. Of the sixty-two N. W. striæ, those occurring in localities in the northern part of the State have a greater *westing*, (from 40°–50°), than those nearer the coast. On the other hand, of the seventeen N. E. striæ, the greatest amount of *easting* occurs near the coast, being from 10°–20°. In the interior the great majority, nearly three-fourths of all the N. E. striæ, only vary 5°–10° from a north and south line. One mark on Lake Telos is put down by Mr. Hitchcock as 80° east, but in a region where the glaciation proceeded almost from the due west; this we must think is probably an observation which needs to be confirmed, as the majority of striæ run from 30°–50° W. of N.

Thus the northwesterly course of the glacial grooves and striæ is especially marked in the interior of the State, on the highlands and low mountains, whose stoss and lee sides uniformly agree with this course. But as we approach the coast, the glaciers, whose marks we see, moved down the river valleys and thus assumed a more north and south course and at times, owing to local bends in the depressions, were even deflexed so as to flow from a direction a few degrees east of north. It must be remembered, as Professor Dana has noticed in his remarks on the Mohawk River glacier, that the glacial striæ, when following river courses, were made by local glaciers at the close of the period of great continental[1] glaciers, when the snow line was rapidly ascending, and the *mer de glace* stood much farther in the interior.

Such an arrangement of *estuary deposits*, as noticed below, at the mouth of the Androscoggin River, occurs also at the mouth of the Saco River, and of the Merrimac, and in fact of all the rivers of New England. In tracing the Androscoggin and Saco rivers from their mouths back to their head-waters, we shall find repeated at intervals along their course, wherever a village rests upon the bank, river terraces, resting on ancient marine beaches altered from ancient glacial moraines, flanking a former sea-bottom, consisting of marine clays. In tracing up the Androscoggin, these are finely shown at New Gloucester, Lewiston, Paris, and Bethel, in Maine. At Bryant's Pond is a fine example of a glacial moraine lake. Its northwestern end lies at the foot of hills rising abruptly around and partly enclosing it, while its southeast shore is composed of a semicircular altered moraine rising as a barrier between the pond and the river which flows by it a few rods to the eastward. On the sides of all the valleys lying at the foot of the White Mountains are distinctly seen moraine hills, which, lower down, are rewashed and modified into lake terraces, which were but dilatations of the large rivers, now represented by small mountain torrents and streams.[2]

In passing from Gorham, N. H., to the Glen House we see on each side of the road, fine examples of true glacial moraines which apparently have never been modified by the sea. These moraines, presenting vertical cliffs from fifty to one hundred feet high, of clay and mud and gravel, are mixed in confusion, though near the top of the deposit there is a rude stratification probably similar to what has been noticed in the ancient moraines in the Alps. There is a marked difference between the soft, oozy, treacherous, glacial mud which sticks to the enclosed rounded, worn, and polished boulders, and into which one may sink almost knee-deep, and the tough, tenacious, marine clays of the coast.

This moraine matter I observed, in ascending the sides of Mount Washington, to become gradually freer from the glacial mud, and the soil through which the boulders are scattered becomes more loamy and gravelly. Also, as we ascend the mountain, the boulders become more angular. Half way up the mountain, at a point beyond the limits of growth of the deciduous trees, where the spruces grew from 30 to 40 feet high, the drift was almost wholly composed of boulders, one half of which were angular, while the other half were rounded. As we ascend higher the rocks continue to grow more angular, until just beyond the limit of trees, at a height of 4150 feet, both the boulders and gravel are *all* angular. At this height no foreign boulders of rock differing from the peculiar slate which forms the summit of the mountain, and which, as Prof. Leslie oberves,[3] is not found at the base, were observed. The sides of the mountain, and the summits of Mounts Jefferson, Adams, Clay, and Madison, are strewn thickly with angular masses of granite and mica slate containing staurotide in great abundance. The "Ledge" is an embossed and rounded rock 3840 feet

[1] By *continental glaciers* we would not convey the idea of a *single*, broad, unbroken ice-dome extending from one ocean to the other, but rather of a *system* of vast seas of ice capping the principal water-sheds of *Eastern* North America, and sending branches down the principal valleys. This may be *assumed*, though many years of observation, in British North America especially, are needed to *prove* the existence of such seas of ice capping broad areas of thousands of square miles.

[2] See "Hitchcock's Surface Geology," Smithsonian Contributions. We would, however, rather consider the "moraine terraces" of that learned investigator, as remodelled glacial moraines, which at a later period formed ancient beaches.

[3] *Proc. Amer. Phil. Soc.*

above the sea. Above this point no grooved or striated boulders were perceived. Indeed, there are no indications of the action of the sea in any deposits noticed beyond a height of five hundred feet above its present level, so far as I could discover anywhere in this group of mountains. The same may be said of Mount Katahdin, in Maine. The upper 1000 feet of its height is free from rounded transported boulders. The summit is strewn thickly with huge angular blocks broken off by frosts from the subjacent strata. At the height of about 4000 feet above the sea, at the "Slide" on the south side of Mount Katahdin, is a large mass of glacial moraine matter which has escaped denudation, and this encloses frequent rounded and polished boulders of fossils of the same species of Silurian shells and of the same silicious slates as are found *in situ* a few miles northwest, on Lakes Webster and Telos. The original fine glacial mud adheres firmly to these pebbles. They were evidently rounded by glacial streams and the pressure of the ice itself, and not by the action of sea waves, for writers have noticed a large percentage of such rounded pebbles in the moraines in the Alps. Parallel cases of a transfer of glacial matter from lower to higher levels have been noticed by geologists both in this country and in Northern Europe. Apparently the boulder containing the Silurian Brachiopods came from the horizon now developed on Webster and Telos Lakes, as the species I collected from both localities is the same in the beds at Webster Lake as that found on the mountain. The theory that the boulders were carried up by icebergs seems untenable, since the parent beds are but about twelve miles distant.

Above this point on the mountain there were no loose, rolled boulders, but the peak was covered by loose blocks detached by the powerful disrupting agency of the frost from the underlying rock, as in the five higher peaks of the White Mountains, and the higher of the mountains of Labrador above the rounded hills, 1000–2000 feet high, at their base. It should be noticed that the summit of Mount Katahdin is a true "needle" or sharp peak, being a short ridge on which two men cannot walk abreast with safety, and along which in wet or windy weather it is perilous to walk from danger either of slipping down or being blown over the precipice which on each side descends thousands of feet. Thus it seems reasonable to infer that the sea has not risen more than perhaps five or six hundred feet above its present level either in the mountainous portions of New England or over 1200 feet in any portion of the Labrador Peninsula. On the other hand, the White Mountains and the higher mountains of Maine all seem to differ from the high mountains in the northern termination of Labrador, in presenting one grand stoss and lee side. The long slopes toward the northwest, and the mural southeast faces are as well marked as the embossed rocks rising out of the lowlands at their base. The highest five hundred feet of Mount Washington, and probably the summits of the surrounding peaks, and the top of Mount Katahdin, probably, as stated by Professor Agassiz, rose to break the otherwise icy expanse, as at the present day granitic peaks rise out of the *mer de glace* in the Alps, Greenland, Spitzbergen, and Norway. This difference between the N. W. and S. E. sides is especially seen after riding through the "Notch" from Conway, and then taking the new Cherry Mountain road from the "Notch" around by way of the town of Jefferson to Gorham. All the narrow valleys, deep precipices, the more rapid torrents, and the loveliest as well as grandest scenery, is found on the southerly aspect of the mountains. On emerging from the "Notch," we soon come out into the broad intervals and tracts, many square miles in extent, bordering the banks of the Ammonoosuc River; and there is a gradual, steady ascent from the plain up to the summit of the mountain, in striking opposition to the sudden ascent from the opposite side.

The deposits of gravel uniformly spread over the temperate zone, capping the clays and lying unconformably upon them, are, I conceive, derived from the upper part of the original moraine matter, and it is not necessary to explain its presence by introducing a new and more recent glacial period. Thus a continuity can be traced between the gravel deposits as they occur unconformably to the clays beneath, and as they occur in the White Mountains in an unwashed, undisturbed state, where they form a part of the original glacial moraine matter, differing only in having less mud in its mass and more gravel, and in lying at the top of the mass. This is the natural arrangement of moraine matter as described by writers on glaciers, who state that the mud is formed at the bottom of glaciers, while the gravel, transported blocks, and detrital matter are hurled down by avalanches upon the back or upper surface of the glacier. The sea, as it gradually encroaches upon the terminal moraine of the retreating glacier, would naturally seize and throw down on its bottom the finer mud of the lower part of the moraine mass, and the heavier gravel and trains of boulders would retain their position throughout the entire process of denudation. It is thus that the gravels, sands, and trains of boulders are always uppermost in the series.

The great point of interest in connection with a glacial theory, is to learn whether the White Mountains, and larger mountains of Maine, were centres of glacial action like the mountains of Switzerland, Scandinavia, Greenland, and the Himalaya Mountains, in the present day, and the Highlands of the British Isles, of New Zealand, and the Rocky Mountains, formerly. It would naturally be supposed that at the close of the glacial period, there would be left about this group of Alpine heights small glaciers descending the valleys.

Since this paper was presented for publication, additional observations made in the White Mountain Valleys, watered by the Androscoggin and the tributaries of the Saco, afford proofs that local glaciers radiated from the central peaks as in the Alps and mountains of Norway. At Jackson, N. H., on Thorn Mountain, which lies just south of Tin Mountain, there are some well-marked glacial scratches running N. 25° W., and which point directly towards Mount Washington, which stands at the head of the valley of the Ellis River. On the same mountain and hills lying below, are boulders of mica slate conaining numerous crystals of staurotide, beds of which occur only near the summit of Mount Washington, from which they must have been transported.

The summit of Mount Kearsarge, 3400 feet high, is rounded by ice. Dr. C. T. Jackson, in his "Report on the Geology of New Hampshire," states that half way up the mountain the drift scratches run N. 30° W., being about the same course as on Thorn Mountain. He also states that on Mount Chicorua the striæ run N. 35° W. (S. 35° E.), which is the general course of the Ossipee Valley southeast of this peak.

On a hill just east of Goodrich's Falls, on the Ellis River, are very distinct ice-marks on polished surfaces, with striæ running N. 30° W., and lunoid furrows with the opening of the crescent pointing up the valley in the same general direction as the grooves.

Crossing over the mountains into Chatham, N. H. and Stowe, Maine, into the valley of the Cold River, another tributary of the Saco, we find another set of striæ running in quite a different direction. On Speckled Mountain, which lies just east of Mount Royce, the grooves and lunoid furrows point N. 15° E., following the course of the valley at this place, and aiming, so to speak, at a higher peak to the North and East.

On Mount Baldface, 3600 feet high, three or four miles southwest of Speckled Mountain, the glacial grooves are very clearly indicated both below and directly upon the summit. Here they run N. 10° W.; and it might be mentioned that the Cold River Valley turns more to the southeast at this point. On a shoulder of the mountain, three hundred feet perhaps below the summit, the lunoid furrows are very abundant. On the summit of this mountain, which is made up of a light-colored fine syenite, were a few boulders of a peculiar porphyritic syenite, with oblong crystals of albite. Following the N. 10° W. course, less than a quarter of a mile, we traced this train of boulders to the parent rock on Peaked Mountain, of which this mountain is composed. This elevation is perhaps one hundred feet lower than that of Mount Baldface.

Again, crossing the high range of mountains over into Gilead, in the Androscoggin Valley, glacial marks occurred on a high ledge near the river, indicating that the ice moved from the northwest, pursuing the general course of the valley at this point.[1]

Here, then, are good proofs of distinct systems of glaciers radiating from a central *mer de glace* which probably capped the White Mountains. This dome of ice must, so far as our slight observations show, have been soon subdivided into local glaciers, which pursued their route down the different valleys to the sea. Thus following down the Androscoggin River, at Lewiston, as I am informed by Mr. George J. Varney, the ice-marks run nearly north and south, corresponding with the course of the valley at that place. At Brunswick, on the sea-shore, there are deep furrows running in a northwest direction, following the ancient course of the river where it undoubtedly entered the sea up to a late period of the Terrace Epoch.

There is the clearest evidence in the remains of terraced beaches that, so far as we can judge by the slightly stratified state of the drift material, all the present valleys of the White Mountain streams, viz.: the Peabody River, the Ellis River, the Saco, Ammonoosuc and Moose rivers, which radiate from the base of Mount Washington, were formerly occupied and filled to the depth of many hundred feet by large bodies of water. Thus in the Glen the Peabody River is on its northwest bank lined by a series of terraces which rise four in number up to at least 1000 feet above the level of its junction with the Androscoggin at Gorham, though the terraces are best marked six miles from its mouth. The higher of the terraces are broken into hills, the "moraine terraces" of Professor E. Hitchcock; and in their characters can be noticed all the modifications so fully described in general terms as well as in a more detailed form, in Dr. Hitchcock's "Illustrations of Surface Geology." Similar moraine terraces with the lower lying, and consequently more recent terraces, are seen bordering the other streams just named. The moraine terraces ascend the sides of the mountain at least 2000 feet above the level of the sea, and the masses of slightly stratified drift material, found 4000 feet above the sea, are perhaps a continuation of the same moraine terrace, being drift material partially arranged by water, probably very fresh,

[1] Since this paper was placed in the printer's hands, Mr. G. L. Vose thus writes me — proving the existence of a Peabody River glacier, which moved down from the northeast side of Mount Washington, and also confirming our theory of an Androscoggin River glacier. "I noticed last summer, furrows on top of Mount Hayes running about S. 40° E. (N. 40° W.) magnetic; while about a mile up the Mount Washington carriage-road are furrows running S. 30° W. (N. 30° E.), and about two miles up, S. 25° W. (N. 25° E.), magnetic. The variation of the needle thereabouts is about 14° W., so that the reduced courses of the furrows would be: on Mount Hayes, S. 54° E. (N. 54° W.), and on Mount Washington, S. 16° W. (N. 16° E.)" These last furrows point down the Peabody Valley. Near the Alpine House at Gorham, on each side of the valley of the Peabody River, are high, steep cliffs of unmodified glacial drift, which must be the remnants of a terminal moraine thrown across the valley, while the more superficial and middle portions of the moraine have been remodelled into the river terraces, of which there are two sets, beautifully marked; especially the delta terraces of the mouth of the Peabody River, in front of the Alpine House. Mr. Vose also suggests that the "old Peabody River glacier, if I may venture on the expression, may have dammed up the Androscoggin at Gorham."

and running *down stream.* The slight sections seen in the lower levels of the moraine terraces presented, by the arrangement of the boulders and shingle in reference to the whole mass, quite a striking resemblance to the present position of the boulders in the mountain streams. All the stones were so arranged as to present a stoss side toward the mass of waters pouring over them — the longer slopes of the stones always facing up stream, the steep sides down stream. The stream had arranged the stones large and small with reference to gliding over its stony bed with as little hindrance and friction as possible.[1]

It is thus evident that during the Lake Period, or Epoch of Great Rivers, these White Mountain glens were filled with glacial lakes, restrained by barriers thrown up by terminal moraines, which the supposed previous presence of the sea was not sufficient to remove, but which yielded to the power of large masses of water running down stream through the mountain gorges. Slight remnants of these huge glacial deposits still exist as terraced fresh-water beaches on each side of the deep mountain valleys.

Localities of Fossils in New England. Starting from the border of New Brunswick we will proceed to describe in detail the characters of the drift beds and their fossils, going south and eastwards.

Calais. Seven miles below Calais, on the banks of the St. Croix River, is a deposit described to me by Mr. C. B. Fuller of Portland, which agrees, as stated by him, with the clays of Eastport and Campo Bello Island. Mr. Fuller found here *Leda truncata* in abundance, forty-five feet above the level of the river.

I am also indebted to Mr. Fuller for the following list of shells found by Mr. De Laski two hundred and seventeen feet above the sea, three miles above the Fox Island Thoroughfare at North Haven, in a bed of marine clay overlaid by a layer of "blue sand" eighteen inches in thickness: —

Pecten islandicus, Mytilus edulis, Astarte semisulcata, Serripes grönlandicus, Saxicava distorta, Mya arenaria, Mya truncata, Buccinum undulatum, Buccinum tenue Gray, *Natica pusilla (grönlandica), Balanus balanoides.*

Eastport. Professor A. E. Verrill has found at Prince's Point, Eastport, Maine, *Nucula antiqua (N. expansa), Macoma sabulosa, M. fusca, Cardium islandicum, Saxicava rugosa,* and *Pholas crispata* Linn. These specimens I have seen, and also have collected with Mr. C. B. Fuller, upon the island of Campo Bello, at the shore opposite Lubec, *Leda truncata (portlandica), Macoma sabulosa, Mya arenaria* and *Buccinum undulatum.* These occurred just above high water-mark, in a blue clay bank twenty feet thick, resting on the rocks underlying the island.

Waterville. I am indebted to Professor Hamlin of Waterville College, for a list of fossils from the Waterville clays, which are in the college cabinet and were labelled by Professor Loomis several years since. Among them were *Purpura lapillus,* and a *Natica.* There were several specimens of *Buccinum grönlandicum.* The list also contained "*Mya arenaria, Nucula antiqua, N. tenuis? Mytilus edulis, Fusus tornatus, Balanus,* and remains of a Crustacean, together with a crab's claw."

Beds at Bangor, like those at Gardiner, contain *Astarte Banksii* Leach, *Astarte compressa* Linn, (*elliptica*) and *Mya arenaria.*

[1] My attention having been called to this method of arrangement of stones forming the bed of a stream by a paragraph, and wood-cut illustration, in Sir Charles Lyell's *Antiquity of Man,* I was incited on the spot to extend the comparison to the material composing the moraine terrace.

Augusta. The following species were collected by my friend Mr. C. G. Atkins, from the river bank just above the dam.

Pecten islandicus Linn. Abundant as usual.

Leda portlandica Hitchc. Abundant.

Mytilus edulis Linn. Abundant.

Ostræa canadensis. This species is inserted on the authority of Professor Desor, as specimens collected by him are in the Museum of this Society.

Astarte compressa Linn. (*A. elliptica* Brown.) Common.

Astarte semisulcata Leach. Frequent.

Astarte striata Leach. Rare.

Cardium pinnulatum Conr. Not common; also in a collection made by Professor Desor, in the Museum of this Society.

Serripes grönlandicus Beck. Frequent.

Macoma grönlandica Stimps. Common; showing that the deposit was near the upper level of the Laminarian zone, as also does the presence of large *Myæ* and *Mytili.*

Macoma sabulosa Sprengel. Common and large.

Mya truncata Linn., var. *uddevallensis.* Common.

Mya arenaria Linn. Abundant and large.

Saxicava arctica Desh. (*S. rugosa* Linn.) Common.

Natica clausa Sowb.

Natica grönlandica (Beck.) Both species were not uncommon.

Buccinum grönlandicum Hancock. Of the usual frequency.

Buccinum tenue Gray. (*Buccinum scalariforme* Beck.) One imperfect specimen.

Buccinum glaciale Linn. One specimen occurred.

Buccinum undulatum Möller. A specimen collected by Desor is in the collection of this Society.

Balanus Hameri Ascan., collected by Mr. C. G. Atkins, occurred at Vassalboro.

Gardiner. The deposits of Gardiner possess great interest owing to their unusual thickness, and the rich assemblage of marine invertebrates which occur from the lowest to the higher strata, and from the occurrence of the teeth of the bison, and of the walrus, which were dug out of the beds at a distance of fifteen feet from the top of the clay, during Sir Charles Lyell's second visit to this country. He states that the teeth of the bison were forwarded to London, where they were identified by Professor R. Owen. The intermingling of the bones of the walrus and bison in the same beds, shows the great range both of Arctic and Temperate forms during this period. It is parallelized by the similar intermixture of *Leda truncata,* now peculiar to the seas of Spitzbergen, with shells, for example, *Cardium pinnulatum,* more characteristic of the present fauna of Maine. This clay formation rises in conical hills of over one hundred feet elevation above the level of the river, rising from the railroad, which is eighteen feet above high water, and twenty feet above the sea level, while their summits are capped by thick beds of coarse marine gravels often thirty feet thick. The marine gravel which overlies them has been greatly denuded by the action of the river which has formed out of this material the series of river terraces which rise about half way up to the summit of the hills. This clay formation extends continuously down the river to the coast, constantly spreading out into a broader area and rising into low hills and broad undulating fields as it approaches the coast, there presenting beds of similar lithological characters, and with much the same zoölogical assemblages, as at Brunswick and Saco.

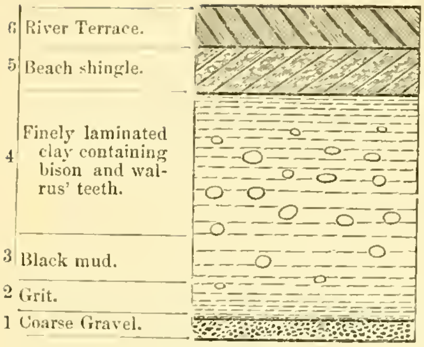

FIGURE 3.
Ideal Section of Quaternary formation at Gardiner, Maine.

A section given in the ascending order, shows the following succession of beds and their characteristic fossils: —

1. A few feet of unfossiliferous gravel resting directly upon the gneiss rock.

2. A few inches of a sandy grit, which weathers into an exceedingly hard sandstone, rich in life, containing *Membranipora americana, Lepralia variolosa, Pecten islandicus, Pandorina arenosa, Astarte Banksii, A. elliptica, Serripes grönlandicus, Natica clausa, Fusus tornatus, Buccinum grönlandicum.* Similar gritty sands are found in patches in the clays above.

3. A soft black clay with a strong odor of marsh mud, containing shells and the remains of Algæ.

4. These beds gradually pass into what the brick-makers call "bar clay." It is about seventy-five feet thick and is very finely laminated, very evenly bedded, consisting of layers an inch thick, separated by thin laminæ of a pure silicious sand. It also contains a few polished and scratched gneiss and greenstone boulders scattered through its mass. Here nearly all the fossils mentioned in the accompanying list occur.

The lowest bed of gravel I did not myself see, but it was described to me by the former proprietor of a pottery manufactory, as resting directly upon the solid rock, as it is often penetrated in boring for wells, and is thus found to be absent in many places about the town, as very frequently the rock is reached directly after digging through the black mud or clay. Most of the wells, after being sunk twenty-five feet, terminate in this soft clay, and the water is unfit for use; while very deep wells, sometimes sunk seventy-five to one hundred feet down into the stratum of clean pure gravel, afford the purest water.

The gritty beds near the bottom of the series of clay strata contain deeper sea forms than those above, and the paleontological evidence leads to the conclusion that they formed a sandy, shelly bottom like our submarine banks, swept by comparatively swift ocean currents; that at a later period the currents were not so strong; that the sea bottom changed into the floor of a deep bay or estuary, in which river silt accumulated, where the most delicate shells lived, and the *Natica* deposited its eggs in broad, thin, platter-like masses, and littoral shells, such as *Mya* and *Mytilus*, abounded. Again, the waters growing fresher, more river sand took the place of mud, the shells disappeared from the loamy strata, and then came an era of denudation, and the deposit of the sea shingle and beach sand, which filled up the hollows and inequalities of the boulder clay.

Returning again to the fossiliferous clays, they were found sparingly stocked with boulders of gneiss and argillaceous slate, often highly polished, with shells firmly adhering to them, as if pressed upon them, since they were flattened out, broken and cracked. All these clays, like those everywhere observed in Maine, where weathered, present a rude and unstratified steep cliff with a slight talus of stones at the bottom. The shells most characteristic of this deposit were *Nucula antiqua* and the two species of *Astarte*, *Mya arenaria*, and *Mytilus edulis.* Owing to the pressure of the superincumbent strata, many of the shells, especially the *Nucula*, were greatly flattened, and distorted into a variety of forms very different from the natural shape, reminding us of the distorted shells of the palæozoic rocks. Several forms, if presented to one unacquainted with this fact of distortion, would be readily mistaken for distinct species, as they are often elongated without being flattened, or cracked and broken in the least. In the Saco beds, and in other beds generally, some forms of *Serripes grönlandicus* are much flattened and slightly elongated, differing in this respect greatly from the recent specimens, but all the changes of form evidently took place after the death of the animal. The mammalian remains occurred in the upper part of this series of beds. The bison teeth were taken out by Sir Charles Lyell about fifteen feet from the surface. Throughout the beds occurred in abundance concretions of clay, easily crumbling, which assumed cylindrical or spherical forms upon being hardened by exposure to the air. These have already been noticed by authors. They are evidently concretions around the fronds of Algæ and animal remains. They are very plentiful, and have been observed in abundance only in beds of this horizon.

These beds of clay become more sandy as they reach the top of the deposit, until the beds graduate into a loamy, sandy clay, affording our best arable soil. All these beds, with the exception of the lowest gravelly strata graduate into each other.

5. Resting unconformably upon them is a thick bed of marine coarse gravel or shingle, which evidently once formed a continuous sheet of sand, — an ancient sea-beach, and is now mostly rearranged (6) into river terraces.

Total thickness of the entire formation, about one hundred and thirty feet.

The clay beds containing the fossils enumerated below are gently inclined toward the east, dipping at an angle of about 10° toward the present bed of the river.

Lepralia hyalina Linn. On *Serripes grönlandicus.*

Lepralia variolosa Johnst. Several patches in shells of Buccinum.

Membranipora americana D'Orb. Occurred on *Pholas crispata.*

Pecten islandicus Linn. Large and coarsely ribbed ; not very abundant.

Leda buccata Steenstp. (*L. Jacksoni* Gould.) Of the typical form.

Nucula antiqua Mighl. Very abundant, and finely preserved, the greenish brown epidermis preserving its original hue and lustre. Some very large and flattened forms occurred with those much elongated and much shorter from beak to lower border than in the typical, ventricose form.

Mytilus edulis Linn. The common form, young and old, were very abundant, and also the variety *pellucidus.*

Mytilus discrepans. (*Modiolaria nigra* Gray.) A few valves.

Astarte compressa Linn. (*A. elliptica* Gould.) Abundant, but not so common as the forms of *A. Banksii.*

Astarte Banksii Leach. (*A. Richardsoni* Reeve.) Common. The fossil forms agree precisely with those living, which I have dredged abundantly in Labrador.

Serripes grönlandicus Beck. Common.

Cardium pinnulatum Conr. Frequent.

Pandorina arenosa Sacchi. A few valves.

Mya arenaria Linn. Very abundant.

Pholas crispata Linn. One valve larger than common in recent forms.

Natica clausa Brod. et Sowb. Some specimens were greatly flattened, the spire appearing as if driven in to the body of the shell.

Buccinum grönlandicum Hancock. This species occurred in a broken and generally imperfect state. Some were large and the waves very much developed. Others occurred smaller, with the outer layer of shell off, corresponding with forms from Portland and Augusta, and agreeing well with the characteristic drawing in Lyell's paper on the fossil discovered at Quebec by Capt. Bayfield (Trans. Geol. Society, vol. vi. 1842, p. 135).

Fusus (Sipho) tornatus Gould. Frequent and of large size.

Spirorbis sp.

Balanus crenatus Brug. Frequent.

Balanus Hameri. Frequent.

Hyas aranea (Linn.) The claws quite large, showing that they belonged to individuals of maximum size, occurred rarely.

Mallotus villosus Cuvier. This was first detected by Mrs. F. Allen of Gardiner, and identified by Sir Charles Lyell. It is rarely found. Sir C. Lyell, in a letter to Mrs. Allen, observed its occurrence at Saco, having been found by a person in that town.

Rosmarus obesus Illiger. In the cabinet of the late Mrs. F. Allen is a walrus' tusk which, I am informed, was taken to London by Sir C. Lyell and identified by Professor Owen.

Bos americanus Gmel. [Plate viii., fig. 18, a, b,] A third upper molar and first premolar tooth are in the collection of Miss Allen of Gardiner, to whose kindness in loaning these unique specimens I am greatly indebted. A second upper molar belongs to the museum of this Society. They agree in all respects with those in a skeleton in the museum of this Society.

Lewiston. From a deposit of arenaceous clay finely laminated, has been taken, at a height of one hundred and ten feet above the sea, a finely preserved specimen of *Asterias vulgaris* Stimps., which is in the museum of this Society. Near this locality *Mya arenaria* and *Leda truncata* have been forwarded me by my friend Mr. George J. Varney of that city.

Brunswick. The drift deposits at Brunswick contrast most widely with the equivalent beds which we have described as occurring in Southern Labrador. All the three divisions of the drift here develop their characteristic features. Resting upon the grooved and striated (N. W. and S. E.) gneiss rocks which underlie the town, we have a thick bed of blue tenacious fossiliferous clay which inclines gently toward the south. Upon this lies the brick-yard clay, or modified drift into which the lowest beds graduate, which is always well marked, and forms a large proportion of the arable land of the town. It is exposed for miles along the shores of Casco Bay, on the river, and artificially. It is from this bed that most of the boulders are derived. Again, resting upon the boulder clay, and filling up its irregularities, is a broad sheet of stratified sand which forms the arid plain upon which the town is situated. It is four miles long and five wide, and slopes gently toward the sea at the rate of about fifty feet in three miles. This sandy plain must formerly have been the bottom of a shallow estuary into which the Androscoggin emptied its waters before the Terrace Epoch, while the immense bodies of water were draining off, during the elevation of the coast. For it was after the deposition of this immense body of sand, evidently the terminal moraine of a local glacier, which scooped out the river bed of the Androscoggin, that the river was turned eastward in its course, and emptied its waters into the Kennebec, after which these sands were reassorted into terraces.

These terraces are six in number upon the south side of the river, while upon the opposite, or Topsham side, there are but two straight parallel ones which run nearly east and west, following the course of the river at this point. Upon the south, or Brunswick side, of the river, the highest and earliest formed terrace is indistinctly marked, and turns southward from the river at nearly right angles to its present bed. The remaining ones are longer, more perfectly formed, and assume successively a direction more parallel with that of the river, until the two lower and most recently formed terraces lie almost exactly parallel to the two opposite ones upon the northern side of the river.

The locality of fossils situated farthest inland is at the "Railroad Cut," two miles and a half westward from the depot, eighty feet above the level of the sea, and about three miles distant from it. Upon the western slope of the gneiss hill through which the road has been blasted, lies the fossiliferous blue clay. At this point *Nucula antiqua, Leda truncata* (*portlandica*), *Mytilus edulis, Cryptodon Gouldii, Mya arenaria, Saxicava arctica,* and *Pandorina arenosa* occurred.

By digging for the construction of wells, anywhere through the sandy strata of the town, the blue clay is found at the depth of ten to thirty feet. Besides the shells of *Mya arenaria* and *Mytilus edulis* in all stages of growth, we find in their usual relative abundance, *Nucula antiqua, Leda truncata* (*portlandica*), and occasionally *Pandorina arenosa.*

These beds correspond perfectly with the higher beds of the Leda clay on the Kennebec and Penobscot rivers, and at Portland.

The lower horizon of fossiliferous clays is developed in several localities on the shores of Casco Bay, one of the most interesting of which is found at high-tide mark on the western shore of Mere Point. The shores of the Bay, in the more retired arms and reaches, are largely composed of cliffs of the boulder clay, which though always stratified, consisting of a tough blue clay at the bottom of the beds, graduates at the top into a lighter, more loamy clay, and abounds in sea-worn erratics. Where this boulder clay has been denuded on its surface, the land is invariably found thickly strewn with boulders, more so than in the more recent brick-clays farther inland. Besides the remains of sea-weeds were stems of a sedge-like plant and smaller portions of land plants too indistinct for identification. In the upper part of the beds, near the surface, concretions of clay formed about the stems of vegetables, occurred in great abundance.

Lepralia nitida (Fabr.) Rare. The living form has not yet been detected on our coast south of Greenland.

Lepralia annulata (Fabr.)

Hypothyris psittacea King. One valve occurred.

Nucula antiqua Mighl. (*N. expansa* Reeve.) Abundant.

Leda buccata Steenstr. (*N. Jacksoni* Gould.) Numerous.

Leda truncata Brown. (*N. portlandica* Hitchc.) Numerous.

Pecten islandicus Linn. Very abundant and large.

Serripes grönlandicus Beck. Common.

Macoma sabulosa Stimps. Frequent.

Astarte compressa Linn. (*A. elliptica* Brown.) Very abundant.

Astarte Banksii Leach. Rare.

Astarte striata Leach. Rare; fine large valves. [Plate vii., fig. 1.]

Mya truncata Linn. The short form frequently occurred.

Saxicava arctica Desh. Numerous.

Fusus (*Neptunea*) *tornatus* Gould. Abundant and very large, some specimens nearly four inches in length.

Buccinum undulatum Möller. Large. Specimens occurred of both the short common form, and the long variety which we have only seen growing in Labrador.

Balanus porcatus Da Costa. (*B. crenatus* Brug.) Abundant.

Portland.

The drift beds at Portland resting upon Bramhall Hill, a rounded gneiss hill 175.5 feet above the mean sea level, dip at rather an unusual angle, 15°–25°,

S. E. and N. W. on each side of the hill, following the natural declivity of the rock. They agree closely with those described at Gardiner and Augusta, with slight local variations; consisting, in the upper beds, on S. E. side of the hill on Canal Street, of more frequent alternations of arenaceous beds. First, in ascending order, is a bed of hard blue clay containing the numerous deep-sea forms enumerated below, which have been found at this locality by Mr. C. B. Fuller, without whose kind assistance this list could not have been prepared. These beds of pure clay pass into beds containing patches of sand and grit, until at a level varying from twenty-five to forty feet above the sea, following the slope of the surface, the beds are composed of sand, with an almost entire absence of boulders, but containing a few angular pebbles of quartz. These sandy beds alternate with thin beds of fine sandy mud, in which abound very perfect casts of *Euryechinus dröbachiensis,* numerous valves of *Serripes,* united valves of *Mytilus edulis,* and very perfect casts of the holes of *Mya arenaria* (see figure 4, near the top), showing that the animal after death had been replaced by mud, which had been washed into the empty shell, thus proving the tranquillity of the waters of that period.

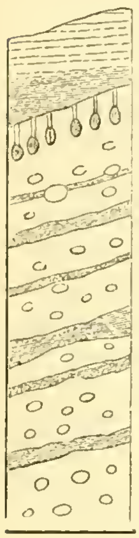

FIGURE 4. Section of beds at Portland, Me.

We have never found living specimens of *Mya arenaria* of such great size and abundance growing with *Serripes grönlandicus,* and in almost equal abundance, as the latter is usually, in Labrador, only found in from ten to twenty fathoms. The presence of *Euryechinus* in abundance also shows that the sea could only have been four or five fathoms deep, while the beds of clay lower down in these series must have been deposited in a sea ten to twenty-five fathoms deep.

This deposit is unconformably capped by very thick beds of coarse sand and shingly gravel, precisely as at Gardiner, and about Boston. The lowest beds of tough blue clay are of the same origin as at Mere Point, Brunswick, while the brickyard clays inland are on the same horizon with the higher and more sandy beds. This point was more exposed to oceanic currents and tidal action, as evidenced by the frequent alternations of sands and sandy beds of clay, while the brickyard clays were deposited in estuaries and quiet protected bays. In these frequent alternations of beds of sand, which by their evenly bedded strata indicate a period of great tranquillity of the sea, we see evidence of a continued, slow, and almost imperceptible depression of the land during all this period.

Euryechinus dröbachiensis (Möll.) Found by Mr. E. S. Morse and myself very abundantly and well preserved in nearly entire casts on Canal Street.

Eschara elegantula D'Orb. Canal Street.

Stomatopora expansa Pack. On *Buccinum undulatum.*

Lepralia sp.

Membranipora americana D'Orb. This well-known form is not uncommon on shells.

Pecten grönlandicus Sowerby. Specimens from Mr. C. B. Fuller were thus identified by Dr. Stimpson. (*P. similis* Laskey? Fuller in the Report of the Maine Scientific Survey, 1861.)

Pecten islandicus Linn. In the usual abundance. From Mr. E. S. Morse.

Nucula antiqua Mighls. Bost. Journ. Nat. Hist., iv. 1844. (*N. inflata* Hancock. Ann. and Mag. Nat. Hist., 1836.) Common.

Leda buccata Steenstr. Frequent. From Mr. Fuller.

Leda tenuisulcata Couth. This I have received from Mr. Fuller. It is a well-marked specimen, agreeing precisely with the living forms, and is readily separated from any varieties of *L. buccata.* Its occurrence here and at Saco is interesting, as showing that this locality was at the northern limits of the Acadian fauna of the Quaternary period.

Yoldia pygmæa Münster. (*Nucula lenticula* Möll.) I have compared the fossils with the recent shell from Greenland labelled "*lenticula* Möller," received through the kindness of Dr. C. Lütken of Copenhagen, and find no differences between them. It is not uncommon both here and at Saco. From Mr. C. B. Fuller.

Mytilus edulis Linn. Very abundant in the higher levels of the clays associated with *Euryechinus dröbachiensis* and *Serripes grönlandicus.* In a higher bed in another part of the city occurs a beach deposit formed largely, according to Mr. Fuller, of the comminuted angular fragments of this species, and among them occurred a valve of *Pholas crispata* Linn., now in the collection of Mr. C. B. Fuller of Portland, who has discovered most of the forms here enumerated.

Astarte compressa Linn. (Not *A. compressa* Montagu, Forbes, and Hanley; *A. elliptica* Brown.) Common. Morse, Fuller.

Astarte Banksii Leach. Abundant. Forms closely resembling, if not identical with, specimens of *A. Lawrentiana* received from Dr. Dawson show that the latter is but a variety.

Astarte striata Leach. Not infrequent; associated as usual with the preceding species.

Astarte lactea Brod. et Sowb., Gould! Rare. (Fuller.)

Cardium Hayesii Stimps. Rare. Fuller.

Serripes grönlandicus Beck. Abundant in what must have been the bottom of a much shallower estuary than the species is now known to inhabit. On the coast of Labrador it abounds in muddy bays, ten fathoms deep.

Mactra polynema Stimps., Smith. Misc. Coll., no description. (*M. ovalis* Gould.) Not uncommon at Zeb's Cove, Cape Elizabeth.[1]

Macoma sabulosa Spgl. In the usual abundance, though not so much so as in the Labrador deposits.

Solen ensis Linn. Collection of Mr. Fuller.

Mya arenaria Linn. Abundant.

Mya truncata Linn. Common.

Saxicava arctica Desh. Common.

Pholas crispata Linn. Rare.

Margarita cinerea Gould. Rarely found.

Natica affinis Gmel. (*N. clausa* Brod. et Sowb.) Frequent.

Natica (*Lunatia*) *grönlandica* Beck. Frequent.

Natica (*Amauropsis*) *islandica* Gmel. (*N. helicoides* Johnst.) Coll. Portland Nat. Hist. Soc.

Buccinum undulatum Möller. (*B. labradorense* Reeve.)

Buccinum plectrum var. *Packardi* Stimps. Can. Nat., Oct. 1865.

Dr. Stimpson quotes his typical recent specimens from near Behring's Straits, where they "were dredged alive in twenty to thirty fathoms, in the Arctic Ocean north of Behring's Straits, by Capt. John Rodgers, U. S. N."

Buccinum Totteni Stimps., Can. Nat., 1865. Frequent.

Buccinum grönlandicum Hancock. Frequent. Specimens in the Collection of Mr. Fuller agree well with Lyell's figure of "*B. angulosum*," a synonym of this species.

Buccinum cretaceum Reeve. Pack., Can. Nat. and Geol., Dec. 1863, pl. ii., fig. 6.

[1] See also a list of fossils found at this locality by Dr. Wm. Wood. *Proc. Portland Soc. Nat. Hist.*, i. 1862.

Fusus (Neptunea) 10-costatus Say. A specimen has been received from Mr. Fuller.

Fusus (Neptunea) tornatus Gould. Frequent.

Spirorbis nautiloides Lamk.

Balanus porcatus Da Costa. (*B. geniculatus* Gould.) Frequent.

Eupagurus Bernhardus Stimps. Specimens of claws were received from Mr. Fuller.

Hyas aranea Leach. Fine large specimens have been received from Mr. Fuller and Rev. E. C. Bolles.

Cancer borealis Stimps. Numerous specimens from Westbrook, with the preceding, from Mr. Fuller.

Saco. The beds at Saco are brickyard clays on the bank of the Saco River, about ten miles from its mouth, and agree very closely with the same beds at Gardiner, and are doubtless on the same horizon as the beds at Westbrook, occurring about the same distance above the sea. Mr. Fuller has very thoroughly explored these beds, and the numerous specimens of fossils received from him agree precisely with those from Gardiner. The *Nucula antiqua* and *Naticæ* have been flattened out by pressure as in the Gardiner specimens.

Idmonea atlantica (*I. pruinosa* Stimps.) Rare.

Modiolaria discrepans Möll. Frequent and very large.

Nucula antiqua Mighl. Abundant.

Yoldia myalis Couth.

Yoldia pygmæa Münster. (*Y. lenticula* Möll.)

Leda tenuisulcata Couth. Not common.

Leda (Yoldia) arctica (Gray.) Parry, Voyage, 1824, p. 241. (*Leda truncata* Brown; *L. portlandica* Hitchc. Sars, Fossile Dyreleveninger fra Quartaerperioden, 1865. *Nucula siliqua* and *sulcifera* Reeve. Belcher's "Last of the Arctic Voyagers," vol. ii., pl. 33, figs. 1, 2, 3, p. 186.) Very abundant. Found, according to Torell, at Spitzbergen, in from five to thirty fathoms.

Astarte Banksii Leach.

Thracia Conradi Couth. Broken and flattened specimens are not uncommonly found.

Thracia truncata Mighels et Adams. Usually the specimens are somewhat broken and distorted.

Pandora trilineata Say. Very common.

Pandorina arenosa Möll. Not frequent.

Bulla occulta Mighels. (*B. scalpta* Reeve. Belcher's "Last of the Arctic Voyagers," ii. app. p. 392, xxxii. 3, a, b, c.) Also occurred at Scarboro and Westbrook frequently.

Menestho albula Möll. Fine large specimens.

Natica affinis Gould. (*N. clausa* Sowb.) Of large size, as at Gardiner.

There are similar beds at Kennebunk, and also at South Berwick, where the bones of a seal have been found, as mentioned by Dr. C. T. Jackson in his Geology of New Hampshire.

In similar beds at the slide of the Presumpscot in Westbrook and also in Scarboro, a Macoma [Plate vii., figs. 2, 2a.] which is closely allied to, if not identical with, *Macoma fusca*, occurred quite frequently; it was collected by Messrs. Fuller and Morse. It is more ventricose, but otherwise of the same proportions. From *M. grönlandica* it is readily distinguished by being larger, much more ventricose, much more produced anteriorly, while the posterior end is more rounded and produced, wanting the truncate appearance of M. *grönlandica.* The ligamental notch is less distinctly marked.

Length, 1.08; breadth, .32; height, .70 inch.

The occurrence of this species is of great interest, as showing that at this point on the coast there was a decided increase in the temperature of the post-pliocene sea, owing probably to the influence of some branch thrown off from the Gulf Stream. Two other shells, members especially characteristic of the Acadian fauna, such as *Pandora trilineata,* and *Leda tenuisulcata,* find here their most northern limit. The occurrence of *Astarte castanea* at South Berwick, mentioned by Dr. C. T. Jackson in his Report on the Geology of New Hampshire, is a further proof of the boreal character of these beds, in distinction from the subarctic or Syrtensian beds of eastern Maine and the St. Lawrence River.

The beds at Portsmouth, N. H., as noticed by Dr. C. T. Jackson in his Geological Survey of New Hampshire, are identical with those of Saco and Westbrook. He states therein that Mr. John L. Hayes found *Leda* (*Nucula*) *portlandica* associated with "*Sanguinolaria,*" at a level thirty feet above high tide, in blue plastic clay. This is the most southward limit yet known of *Leda portlandica.*

Point Shirley.

At Point Shirley, as has been shown by Stimpson, the beds dip into the sea over a rocky promontory at an angle of 18°. The forms therein contained are almost exclusively members of the Virginian fauna, being found abundantly in the waters south of Cape Cod, and agreeing precisely with the fossils discovered by Desor in Nantucket, and by Redfield in Brooklyn, New York. At this point the Acadian fauna seems to have merged into a more southern assemblage of animals.

At Point Shirley Dr. Stimpson records[1] the occurrence of the following species, which "occur in the upper part of the stratum of blue clay and pebbles which crops out from under the coarse drift": —

Balanus rugosus,	*Astarte sulcata,*	*Mytilus modiolus,*
Mya arenaria,	*Astarte castanea,*	*Ostræa borealis,*
Solen ensis,	*Cardita borealis,*	*Fusus decemcostatus,*
Mactra solidissima,	*Mytilus edulis,*	*Buccinum plicosum,*
Venus mercenaria,		*Buccinum trivittatum.*

The specimens which I collected were mostly much worn, as are many of those from New York and Nantucket in the Museum of this Society, collected by Messrs. Desor and Cabot.

The following species occur in the neighborhood of New York city: —

New York City.

Venus mercenaria Lamk.

Nassa (*Ilyanassa*) *obsoleta* Say. Specimens of both species are in the Museum of this Society, and agree precisely with those from Point Shirley.

Our knowledge of the drift beds southward of Point Shirley is comparatively scanty, owing to the few fossils that have been found in these beds, and preserved for future reference. But the interest of the subject is greatly enhanced by the fact, that these strata rest directly upon the middle tertiary beds at Nantucket and Martha's Vineyard, and in the vicinity of New York City, as it would seem from Mather's statements in the Report of the Geological Survey of New York. In addition to this, the fact that the contained fossils are forms now living in the adjacent seas heated by the warm currents thrown off from the Gulf Stream, and thus have almost wholly lost their character as an arctic glacial assemblage, shows that the transition from the cooled areas of the Gulf of St. Lawrence

[1] *Proceedings Bost. Soc. Nat. Hist.* vol. 3, p. 9, 1848.

and northeastern Maine was sudden, and no more distinctly marked than at the present day; — any light thrown upon the characters and distribution of this formation south of Cape Cod possesses the liveliest interest.

We have been led to believe that in the drift period, the present course of both the arctic current and the Gulf Stream existed at a very early period of that epoch from Labrador to Florida, and the abundant palæontological evidence now before us proves this to have been the case. It is most probable that during the period of glaciers in the northern parts of the continent, the growth of the coral reefs of Florida and the West Indies was not interrupted; and that a sub-tropical fauna existed in South Carolina, contemporaneously with the sub-arctic fauna peopling the seas of the southwestern coast of Maine, and the more purely arctic, glacial fauna, inhabiting the waters of Labrador and the Gulf of St. Lawrence.

Messrs. Desor and Cabot[1] have happily filled up the gap in our knowledge of the beds on the coast of New England lying just south of Cape Cod, in a paper which we were not aware had been published until most of this article had been prepared for the press, and subsequent to the publication of an abstract of the present article in the American Journal of Science and Arts, New Haven, January, 1866.

The authors give a section of the drift beds, seventy-two feet in thickness, at Sancati Head, forming the eastern extremity of the island of Nantucket, resting upon twenty feet of a brown clay which is referred to the Miocene Tertiary, which is considered as probably contemporaneous with a similar clay underlying the drift at Truro, Cape Cod, and also with the brown sandy clay at Martha's Vineyard, proved by Sir Charles Lyell to be miocene. Resting unconformably upon the brown clay are beds presenting the following section in the ascending order. (1.) a bed of gravel, — two feet; (2.) homogeneous white sand, — four feet; (3.) tough clay, very similar in its aspect to the plastic clay near Paris, except that it contains a great many nodules of ferruginous sand, — one foot; (4.) "an oyster bank one foot thick, intermixed and covered by (5.) large masses of *Serpula;* which are like the oysters, in their natural position," with many other shells, — four feet; (6.) a stratum of worn shells which "bear evident traces of exposure, the valves of the bivalves being generally isolated, and the *Balanus* disintegrated and more or less worn, — two feet." "Above this stratum of loose shells there is found a series of layers of sand and gravel, with a thickness of nearly fifty feet, in which every variety of materials may be seen, from the finest sand to the coarsest gravel." These beds dipped westward from five to fifteen degrees, the beds becoming less inclined from below upward.

We quote at length the conclusions of the authors, as the paper is not generally accessible to American students: —

"Concerning the drift overlying the tertiary clay at Sancati, it is obvious from the regularity of the strata, and from the very perfect state of preservation of the shells imbedded in it, that it has not undergone any violent disturbance since their deposition. The species collected by us in the above-mentioned oyster bank are the following: —

Venus mercenaria, plenty.
Mya arenaria, plenty.
Ostrea borealis, a bed several feet thick.
Arca transversa, very abundant.
Solen ensis, abundant, but very brittle.
Astarte castanea, rather rare.
Cardita borealis, rare.
Cumingia tellinoides, rather rare.

[1] "On the Tertiary and more recent Deposits in the Island of Nantucket." By E. Desor and E. C. Cabot. *Quart. Journ. Geol. Soc. London*, V. p. 340, Feb. 1849.

Crepidula fornicata, abundant.
Buccinum undatum, rather rare.
——— *plicosum*, abundant.
Nassa obsoleta, abundant.
—— *trivittata*, abundant.
Scalaria grönlandica, rare.
Balanus rugosus, very abundant.
Serpula, forming a layer several feet thick.
Pagurus pallicaris (claws).

"Now these are, without any exception, the same species that are found living on the shore of Nantucket and Cape Cod; and as they are all in their natural position, the bivalves having almost always the two valves united, and the Venus being commonly half open, just as they are found on the beaches when the muscles have relaxed after death, we may fairly infer that in this part of the continent at least, the climate has not undergone any considerable change since the deposition of these fossils.

"The presence of a stratum of disintegrated shells of the same species, resting upon the undisturbed oyster-bank, may easily be accounted for by a somewhat more violent action of the tides, which deposited in this irregular manner a part of the shells which were washed off from the oyster bank itself, in the same way as is the case now among the Nantucket shoals.

"Until last year it was assumed by the geologists of this country that there were no fossils to be found in the drift, south of Lake Champlain and the State of Maine, when one of us had the good fortune to discover several species in the drift of Brooklyn, near New York.[1] Similar fragments, especially of *Venus mercenaria*, have since been found in the cliffs of Point Shirley, in Boston Harbor. Now, as the fossil shells in both places are of the same species as those of Sancati cliff, there is every reason to consider them as belonging to the same period, their more or less perfect state of preservation depending merely upon local influences. It ought further to be stated, that wherever the shells are worn or broken, and the strata which contain them coarse and irregular, it is either in such places where the tidal currents must have been violent, so as to carry and deposit promiscuously heavy pebbles and minute shells, as in the cliffs of Point Shirley; or in such places where we must suppose that floating ice was at work, carrying indiscriminately heavy materials, pebbles and boulders, together with oysters and other shells detached from the neighboring flats, and heaping them up in the corners of bays and sounds. This seems to have been the case with the coarse deposits of Brooklyn, where oysters and Venus are generally found imbedded in a reddish loam intermixed with pebbles and boulders, many of which are distinctly scratched, thus reminding us of similar actions which you have described in Fundy Bay and in the St. Lawrence; whilst in other places like Nantucket and the bays and fiords of Maine, a more quiet action prevailed, so as to allow the shells to be preserved in their natural place and position after death.

"Finally, the fossils of the drift of Nantucket bear such a striking similarity to those of the newer pliocene of the Southern States, that they become a natural link between the northern and southern deposits. Instead of considering these as so many distinct formations, we should therefore henceforth look at them as mere modifications of the same deposit, being the result of the same agencies, viz.: oceanic tide-currents along the whole coast of the United States, combined with gradual and secular oscillations of the whole continent, the local strength of the tidal currents affording a sufficient explanation for local diversity in the arrangement and size of the materials in each locality."

[1] E. Desor's Letter to M. de Verneuil, in the *Bulletin de la Société Géologique de France*, 1847. A most interesting collection of the drift fossils of Brooklyn has since been made by Mr. Redfield.

By the foregoing lists it will be seen that during the Quaternary of the French and Scandinavian geologists, or post-pliocene period of Lyell, the distribution of marine animals was governed by the same laws as at the present day. In going southward from Labrador to New York the seas became warmer the more they came in contact with the heated waters of the Gulf Stream, whose influence was evidently exerted on the coast of New England during the glacial period. The climate of New England was not purely arctic, but rather sub-arctic, where now it is "boreal." While this period was characterized by the wide distribution of what are now purely arctic or circumpolar species, there were also intermingled boreal or Acadian forms. Thus the arctic *Leda arctica*, *Pecten grönlandicus*, *Serripes grönlandicus*, *Pandorina arenosa*, and *Fusus tornatus*, were then wide spread and most characteristic shells from Greenland to Portland, Maine. The Leda especially, abounding in every clay deposit, has now become wholly extinct south of Spitzbergen and the 70th parallel of latitude.

An exceedingly small percentage, if any, of the species has become *wholly* extinct, the only instances occurring to us being the *Beluga vermontana*, about which there must be great doubt, owing to the difficulty of distinguishing the fossil species of whales, and the new species of *Fusus* (*F. labradorensis*), and, possibly, *Bela robusta*, described above.

A considerable number have become extinct in the north temperate seas, owing to the great changes in the climatic conditions. A parallel case is shown in the southward migration and subsequent extinction in Europe of the musk-ox, polar bear, lemming, and other quadrupeds now confined mostly within the limits of the arctic circle.

During the glacial period, or that of the deposition of the glacial beds, (Leda clay of Dawson,) which are unmistakably rewashed terminal moraines left during the incoming or coldest period of the Quaternary, (when, we have every reason to believe, true glaciers of great extent eroded the present river systems as far south as New York,) there was a greater uniformity than now of the climate; but yet, as shown by the distribution of animal life, there was a decided change from a purely arctic to a sub-arctic climate, from Greenland southward.

At present, the arctic or circumpolar fauna is restricted to a district north of the yearly isothermal line of 32°, which thus includes the arctic-american Archipelago, Northern Greenland, Spitzbergen, Nova Zembla, and the coast of Siberia. This is a true *circumpolar* fauna, and can scarcely be said to be Asiatic, European, or American, though members of the group extend in diminished numbers and size down on the Asiatic coast, to Japan, as we are informed by Dr. W. Stimpson and by P. P. Carpenter in the Report of the British Association for 1856; on the European coast as far as the Mediterranean Sea, and on the Eastern American coast as far as New Jersey, where the polar currents give, at great depths, the necessary amount of cold for their existence. South of this circumpolar belt is a sub-arctic zone of life corresponding to the yearly isothermal of 40°. This line starts from near Cape Breton in North America, and includes Iceland, the Hebrides, the Faroe Islands, Finmark, and Northern Norway. On the American coast this fauna is characterized by a small number of species not yet recorded as found in the circumpolar district, which only occur southward in the Acadian district in diminished numbers and impoverished in size. This Syrtensian fauna bears the same relations to that of the Acadian district as that of Finmark, (judging from the data furnished us in the papers of Professor Sars,) does to that of the Baltic, North Sea and Scottish seas, the boreal or Celtic fauna of Forbes, and which is the European representative of the Acadian fauna. We have shown[1] that

[1] *Canadian Naturalist and Geologist*, Dec., 1863. See also the *Proc. Bost. Soc. Nat. Hist.*, Jan. 1866, p. 276.

this fauna is limited to Hudson's Bay, the coast of Labrador, and the northern coast of Newfoundland. Southward it follows the line of floating ice, which partially excludes Anticosti, but includes both the Grand Banks, and those shoals lying to the southwestward along the track of the polar current, which on the coast of New England flows between the coast and the inner edge of the Gulf Stream; along this line lie the Banks, off Nova Scotia, and Maine, and Massachusetts, together with the St. George's Banks and the Nantucket Shoals. Its influence is likewise felt as far south as the shoals lying off the coast of New Jersey. This current would even seem to impinge slightly upon the north side of Cape Hatteras, where Redfield supposes its final influence to have been felt. Returning again to the shores of the British Colonies, we find this *Shoal* or Syrtensian fauna most curiously interwedged with the Acadian or New England fauna. This is owing, without doubt, to the overlapping of the Gulf Stream upon the great polar current. Thus, while the mouth of the Bay of Fundy is properly a Syrtensian outlier, the head of the bay, the coast of New Brunswick, the western side of the Gulf of St. Lawrence, the mouth of the river St. Lawrence on its southern side, and a small isolated area on the southern coast of Newfoundland, sheltered from the polar current sweeping by Cape Race, and on which a small branch of the Gulf Stream may possibly impinge, are outlying areas inhabited by species most characteristic of the coast of New England north of Cape Cod, constituting a fauna termed by Professor Dana the Nova Scotian Fauna, and by Lütken, the Acadian Fauna. Thus between Greenland and Cape Cod there are two distinct faunæ: the Acadian, with outliers situated north of its normal limits, due to the influence of the Gulf Stream, or, perhaps, to the absence of the polar current; and the Syrtensian or Labrador fauna, peopling the coast of Labrador and Newfoundland, sending outliers far southwards, due to the influence of the polar current. Any attempts to split up this area into smaller subordinate districts or faunæ than these must prove unsuccessful, as such distinctions would be highly artificial.

Having shown how these three faunæ are limited at the present day, it remains to notice how this distribution differed in Quaternary times. The arctic or polar current must have sent a branch through the present course of the St. Lawrence River into Lake Champlain, in a general southwestern direction. This current was evidently a continuation of the present Belle Isle current, which even now pushes the cold waters of the Straits far up beyond the island of Anticosti beneath the fresh waters of the St. Lawrence River. It has been noticed by Dr. Dawson,[1] who has satisfactorily shown the effects of this powerful St. Lawrence current, that the post-tertiary fauna of the St. Lawrence, as it has been studied by him at Montreal, Rivière du Loup, and Quebec, was in all its features purely Syrtensian, and identical with that of the colder portions of the Gulf of St. Lawrence, and especially the coast of Labrador.

The clay beds of Canada synchronize and agree in their general features very nearly with those of Maine, as has been already observed by Dr. Dawson. All the beds to the eastward of the Saco River afford a Labrador fauna. About Portland and on the Saco River we are, however, on the limits of the post-tertiary Acadian fauna. Certain common Syrtensian and purely arctic forms there dwindle in size and diminish very sensibly in numbers, and a few arctic species are replaced by Acadian forms.

[1] Address of Principal Dawson before the Natural History Society of Montreal, May, 1864, published in the *Canadian Naturalist*, where he shows that the general southwest striation of the valley was "from the ocean toward the interior against the slope of the St. Lawrence valley." p. 9.

At Point Shirley we have good evidence of the beginning of the Virginian fauna, where *Venus mercenaria* and *Buccinum plicosum* abound. This must have been the northern limits of the fauna so well developed, as noticed by Desor, in the beds of Nantucket, where the temperature of the sea could have scarcely differed from that of the present period. The same may be said of the post-tertiary fauna of South Carolina, and, from what little we know, of that of Florida, where the heated Gulf Stream evidently preserved the same conditions as now, only more checked in its northern limits than at present by impinging more directly on a coast lined with floating ice, as that of Maine must have been in post-tertiary times.

At such a time the increased degree of moisture must have produced a much greater rain fall, the fogs must have been of greater extent, and the snow line must have approached much nearer the sea, than at present, on the eastern coast of America, south of lat. 60°, and glaciers of great extent must have surrounded the mountains of New England. The land fauna and flora must have been that of Labrador. The bison, the *Phoca* (*Pagophilus*) *grœnlandica*, the *Beluga vermontana*, and among plants, the *Potentilla tridentata* and *Arenaria grœnlandica*, (both of which are now found in the colder parts of the coast of Maine,) must have been the characteristic species. Remnants of such a flora and fauna we now behold on our alpine summits. On the top of Mount Washington, the last 500 feet exhibit a purely sub-arctic or Labrador vegetation. We can scarcely call it arctic, for the dwarf spruces and firs are of the same size as in the more unprotected places in Labrador. The same species of weasel which abounds in Labrador, we have seen on the summit of Mount Washington. The insect fauna we must believe is an outlier of the Labrador sub-arctic assemblage of insects, though with certain features of its own. While some Diptera, Coleoptera, and Lepidoptera are identical, certain species, such as *Chionobas semidea*, *Argynnis Montinus* Scudder, differ slightly from any yet found in Labrador, though they may yet be found further north, or may prove to be local species, remnants of a sub-arctic fauna which peopled the surface of New England, living between the coast and the snow line in the interior. As the line of perpetual snow retreated up the mountain sides, the more hardy species followed, while many others doubtless died in the great changes of climate and topography which ushered in the historic period. As there are aërial or alpine outliers, relics of this ancient sub-arctic fauna and flora, so we must consider the present abyssal forms, and outliers of the Labrador marine fauna, — such as inhabited the Banks of Nova Scotia and Northern New England, and the cold waters of the mouth of the Bay of Fundy, — as the remnants of the Syrtensian fauna, which during the glacial period must have been spread very uniformly over this area.

The arctic sea-birds even now breed upon the islands in the mouth of the Bay of Fundy, as they do on the coast of Labrador. I am told by fishermen that the Puffin, *Mormon arctica*, used to breed on Mount Desert. The *Alca impennis* was probably a common bird, as it was once on the shores of Scandinavia and Scotland; there are rumors extant among our oldest fishermen of its having been seen years ago, but within the recollection of men now living, as I am informed by Professor A. E. Verrill; and its bones have occurred in the kitchen-middings of the coast of Nova Scotia. It is known by Rev. Mr. Wilson, a missionary in Newfoundland, to have been common less than forty years ago about the Fogo Islands, on the northeastern shore of Newfoundland, as I have been informed by Mr. G. A. Boardman of Calais, Maine. These birds represent the sub-arctic avi-fauna of New England during the later period of the drift, and owe their extinction possibly to the slow changes of the climate, which must have been gradually ameliorating for two centuries past in the north temperate zone, but more especially to their destruction by man.

All the facts cited above must at least tend to disprove any theory of a former tertiary or post-tertiary continental connection between Europe and America. The fauna and flora of Labrador during the glacial period were too distinct, the oceanic currents could not have allowed any interchange of forms, and the great depth of the sea in Baffin's Bay would have prevented such migrations as Forbes supposed to have taken place from Europe.

The geological history of the American continent, as laid down so clearly by Professor Dana in the Proceedings of the American Association for the Advancement of Science for 1856, proves that the different formations were, during paleozoic, mesozoic, and tertiary times, built around the granitic laurentian nucleus of British America, and gradually proceeded southward. All the tertiary rocks form narrow strips of land along the coast. No well-informed geologist can believe that the tertiary strata formed continuous sea bottoms, — that, for instance, the miocene beds of Spitzbergen were continuous with those of Disco Island in Greenland, or that the Greenland beds are a part of the miocene strata of the southern States. Equally unfounded on general geological principles seems the theory of a tertiary Atlantis, advanced at the present time, especially by Heer and others, though first proposed by Forbes, to account for the distribution of life in the Azores, and the islands lying off the mouth of the Mediterranean Sea. In fact, the fauna as we go southward from the arctic zone, becomes more and more distinct, and it is probable that such distinctions obtained from the earliest palæozoic times. The Silurian fauna of Europe is nearly as distinct from that of North America as the tertiary fauna of England and France is from that of Virginia, as in the latter case insisted on by Sir Charles Lyell in the Quarterly Journal of the Geological Society for 1845.

During glacial times, while the cave-bear, lion, hyena, and aurochs were associated in Europe with the musk-ox, reindeer, and polar bear, in America the bison characterized a far different American sub-arctic fauna. It cannot be said that the glacial fauna of America was derived by immigration from Europe, for not a single feature, peculiarly European in its type, is found in our post-tertiary beds. On the other hand, the glacial fauna of Northern Europe was essentially arctic-european or "palæarctic." Because the musk-ox is found fossil in the turbaries of France and gravels of Germany, it need not be inferred that the European fauna of that period borrowed an American feature. We would rather suppose that the former range of the musk-ox, a circumpolar species, was arctic-european as well as American. In considering the origin of the flora of Labrador, though not possessing a special knowledge of the botany, we would on general principles venture to dissent from the view of Dr. Hooker, that the flora of northeastern Arctic America is essentially Scandinavian in its origin.

The flora of Labrador, so far as we were enabled to observe, follows closely the laws of distribution of the land and sea animals; and any theory that separates the origin of the two assemblages cannot be in accordance with the general laws of the distribution of life, be it plant or animal, over the surface of the globe. The fauna of Australasia is no less peculiar than its flora; the flora of Brazil is characterized by its peculiar tropical American forms, just as the fauna is circumscribed by peculiar features. So we must believe that the origin of the arctic-european and arctic-american and arctic-asiatic floras and faunas was distinct from the outset, and that they have never borrowed, by extensive inter-continental migrations, each other's peculiar characteristics. As we have observed in regard to the animals, there are a very large proportion of arctic plants spread over the whole arctic zone, which cannot be said to be American any more than European or Asiatic, but simply circumpolar. On the other hand, there is a small percentage of which the reverse is true, and this is paralleled among the animals.

Dr. J. D. Hooker, in his elaborate essay on the Distribution of Arctic Plants in the Linnean Transactions for 1861, accounts for the greater richness of the flora of Lapland over that of other arctic regions by the blending of warm and cold currents of air and water, and its great diversity of mountains and low lands; while on the broad plains of Siberia and the level plateau of Labrador there is the greatest uniformity of climate, and hence a corresponding paucity of plants.

The same climatic conditions determine the distribution of marine life. As we go from Norway to Greenland the number of species lessens greatly. Dr. Lütken, in his admirable View of the Echinoderms of Greenland, shows that the fauna is essentially arctic-american rather than European. It is so with the other radiates, and the articulate and molluscan fauna, and the fish fauna would seem to follow the same law. All the facts known to us tend to prove a separation of the two continents even from the palæozoic period.

Dr. Hooker cites fifty-seven species of plants which do not cross from Greenland to America. This is paralleled by the apparent restriction of a few species of marine invertebrates to the high polar seas, such as the *Leda truncata* and *Pecten grœnlandicus*, though in glacial times they abounded in northeastern America.

Among the most purely arctic-american plants are the *Potentilla tridentata*, which is abundant in Greenland and which we have collected in profusion in Labrador, Maine, and on the White Mountains; also the *Arenaria grœnlandica*, which is more thoroughly arctic, preferring the coldest spots on the outer islands of the coast of Labrador, and the alpine summit of Mount Washington, and which has even been detected on Cape Elizabeth, Me., by Dr. G. L. Goodale, of Portland.

These two plants — which Dr. Hooker acknowledges have never occurred elsewhere on the globe within the historic period — he supposes were originally from Scandinavia, though they have never been found in Europe. By this mode of reasoning we might just as well imagine the clam, *Mya arenaria*, to have been derived originally from Europe, or the bison to have been derived from the aurochs of Europe. The presence of such characteristic arctic-american forms in Greenland must destroy our confidence in the supposed identity of the Greenland flora with that of Lapland, for there are strong grounds for regarding the flora of Greenland as arctic and circumpolar simply, rather than European arctic, and that on either side the flora becomes more strongly either American or European, as we go westward or eastward of Greenland.

When, following the line of the yearly isothermal of 32°, we go to the southward on either side of the Atlantic, we find warm and cold currents of air and water intermingling, and thus producing much greater diversity of climate than in Greenland. While the Gulf Stream abuts directly upon Scandinavia, some of its effects are felt in Newfoundland and Labrador. Both lands are continental, and shade into temperate regions. There is a very perfect correspondence in the geology and distribution of the formations, and hence, as Hooker observes, there are a large number (230) of plants, common to Labrador and Scandinavia, which do not occur in Greenland. This is paralleled very exactly in the distribution of animal life. In the seas of Labrador and Newfoundland are found forms derived from the more temperate seas of New England, as on the coast of Norway many forms occur which are derived from the British seas, and are even found as far south as the Mediterranean. These serve greatly to swell the lists. In fact the facies of the flora of Labrador is *sub-arctic* and by no means purely arctic, as is that of Greenland. Explained in this way the flora of Greenland seems to us no more anomalous than its colder climate and remoteness from sub-arctic lands do, isolated as it ever has been by deep seas and powerful oceanic currents of different temperatures, which, we must believe, served from the earliest times as barriers against the commingling of more temperate forms of life with purely circumpolar species.

There is, in our view, no reason to believe that the glacial period, as some writers think, has shifted from the eastern to the western hemisphere, or *vice versâ;* for the same causes which brought on the cold period were evidently common to the arctic and sub-arctic regions throughout their whole extent, though governed greatly by the present distribution of the isothermal lines. That the drift deposits were laid down contemporaneously on both sides of the Atlantic, seems proved by such facts as this: that *Leda arctica* (*L. portlandica*), more than any other shell characteristic of the drift deposits of the northern portions of America and Europe, has become alike extinct both in Scandinavia and its equivalent, Labrador, Canada, and New England.

The break in the glacial beds — which by Sars[1] (in which he closely follows D'Archiac) are divided into an earlier Quaternary or "*glacial*" formation, from which few fossils have been taken, and those purely arctic in character, and the more recent beds, "post-glacial," resting upon them, containing a great influx of *boreal* or sub-arctic and some Lusitanico-Mediterranean species — does not seem so distinctly marked in northeastern America as in Europe. In southern England the able researches of Mr. Searles V. Wood, jun., enable this writer to "arrive at the conclusion that the wide spread boulder clay of England is wholly distinct from the older, but partially developed drift of the Cromer coast. That conclusion was arrived at by the minute examination of more than 8000 square miles of the eastern portion of England, and the grounds for it were submitted to geologists in a detailed map of the drift beds over the whole of that area, with copious sections. It was thus that I acquired the opinion which induces me to deny, as I do, 'that we have yet any evidence of any general submergence at the incoming of the glacial period, far less of repeated oscillations of submergence and emergence.' . . . . . Now although I have endeavored to show that on the east coast of England four oscillations of climate have occurred since the incidence of the glacial period, viz.: first, the extreme cold of the Cromer drift when the country except a part of Norfolk was land; second, the ameliorated climate of the sand and gravel series, which overlies that drift unconformably, and partially underlies the boulder clay; third, the return of cold with the extensive submergence which introduced the wide spread formation of boulder clay; and fourth, the return to sand and gravel conditions, with the elevation and denudation of that clay and the introduction of the post-glacial series — yet the oscillations of climate during the tertiary period begin as well as end with these." — *The Reader*, London, 1865, p. 466.

Having the grand outlines of this formation thus mapped out for us, it remains for geologists in this country to see how far the parallel can be carried out in America. There is as yet everything to be learned of the lowest and oldest boulder clay of the coast of Maine; to ascertain how far it is conformable with the brickyard clays of the uplands,

1 Om de i Norge forekommende fossile Dyrelevninger fra Quartærperioden, etc.; af M. Sars, Christiania, 1865.

and whether there is an overlying bed of sand such as the sheets of sand resting everywhere on the upper boulder clay. At present there have been revealed no signs of this lower bed of sand clay, and the lowest clay beds we are acquainted with seem to graduate into the rewashed, more inland, and more recent boulder or brickyard clays.

In adopting the term *Quaternary Period*, we would use it in the amended sense proposed by D'Archiac in 1848, in his "Histoire des Progrès de la Géologie." From his able review of all the prime characteristics so trenchantly dividing this Period from the Pliocene Tertiary, we are led with that author to consider this Period as rather equivalent to the Tertiary as a whole, than to either of its three subdivisions; and rather as the beginning of a new Epoch or Period, than the close of the Tertiary. The distinctions, as shown by D'Archiac, obtain no less in the tropics than in the high latitudes. In tropical America the period is marked off from the Tertiary by the appearance of the great mammals, the Herbivores characterizing the formation in America, and the great Carnivores the deposit of the Eastern hemisphere. About the Mediterranean the Tertiary Period closed with the upheaval of the Sub-Apennines of Italy, or Alps of Valais.

Professor Dana, in his "Manual of Geology," states further important distinctions, such as the rise of land in the high latitudes which had not before taken place since Palæozoic times, ushering in the Period of great glaciers, and thus serving, over one half of the surface of the globe, to further separate this epoch from the Tertiary.

Another feature of this Period is the great uniformity of climate over broad, continental areas, and the wide distribution in space of certain species most characteristic of the Quaternary Formation. Such are the occurrence, on both hemispheres, of the musk-ox, the Siberian mammoth (*E. primigenius*), and among marine mollusca of *Leda arctica* Gray, Sars (*portlandica*), which is now restricted to the circumpolar seas.[1]

General Conclusions.

To account for all the facts which have been developed above, we must assume, —

I. That the northern portion of North America, that is, the boreal and arctic regions, stood at a much higher level above the sea than now. We have given good evidence that it stood at least 360 feet above that level in Labrador. It would be safe to assume that the coast line stood at an elevation not falling short of 600 feet. While this increase in the

[1] D'Archiac in the *Résumé Général* of the first part of his volume on the Quaternary Period, divides the epoch into five periods — for an enumeration of which we would refer the reader to his volume. But the differences upon which that learned and philosophic author bases his Periods 3 and 4, seem to us not well founded. They both together correspond to our *Leda clay* of the northeast coast of North America. "Période (4), de calme peu prolongée," he characterizes by the "Till and deposits of Arctic shells;" while Période (3), a later one, is characterized by the "Pampæan deposits, the development of the fauna of Great Mammals and marine, fluviatile shells, *identical with the species which still live under the same latitudes*."

On the contrary, we find in Maine, in the upper part of the Leda clay, the remains of the bison associated with *Leda arctica*, a shell now purely circumpolar, while the bison inhabits the temperate zone. The Period 4, then, graduates into Period 3 of D'Archiac. His "Période (2), de transport cataclystique générale et de courte durée," seems to be equivalent to the *Saxicava sands* of American authors.

The lacustrine or Terrace Period of American geologists he also includes in this 3d Période, which is as distinct from the Saxicava Sands as the latter is from the Leda Clays — the three being unconformable and accompanied by distinct oscillations of land.

His 1st and most recent period of existing glaciers in the Alps, and "probably other chains of mountains," accompanied by "polished, striated, and rounded (moutonnées) rocks; gravel, sand, unstratified pebbles, and erratic blocks of the Alps," being of local origin, seems an artificial subdivision when applied to the Quaternary period generally.

The term *Leda Clay*, first proposed by Dr. Dawson, and adopted by the Canadian geologists, characterizes much better this formation in northeastern America than the term *Champlain Epoch*, taken from a shallow inland sea of slight extent, where the strata are but partially developed, and some of the most characteristic fossils entirely wanting.

height of the land would not materially change the physiognomy of the continent north of the St. Lawrence River and Gulf, where the table land rises abruptly from the ocean as in the arctic regions; it would effect a great alteration in the distribution of dry land south of the parallel of 50° N. Should all the present sea-bottom lying within the limits of the depth of one hundred fathoms be thus raised, the Gulf of St. Lawrence would be represented by a river delta, one mouth in the Straits of Belle Isle, the other flowing out between Cape Breton and Cape Ray. All the submarine plateaux, such as the Grand Bank of Newfoundland, and the banks lying off the coast of Nova Scotia, Maine, and Cape Cod, would be elevated above the sea, and probably form broad plains. Thus the effects on the distribution of life would essentially differ from those of the region north of 50° N. Such a rise and enlarged area of land would, as has been stated by physicists, produce an extension southward of an extreme arctic temperature. While the climate would be greatly lowered, we still have added the proximity of the Gulf Stream, as evidenced by the temperate rather than arctic fauna of the glacial beds of New York and Nantucket, aud the more tropical assemblage of South Carolina. Such a blending of hot and cold currents of air and water must have produced even more fogs and a much greater rainfall than now, to feed the enormous glaciers which moved into the sea from off the principal water-sheds.

Thus the snow line descended near the sea level, the shore presented a nearly solid front of glacial ice at least rivalling in height and breadth the enormous glaciers 1000 feet thick and 540 miles long, discovered by Sir James Ross in the antarctic lands. As the ice receded, it left all the marks of intense glaciation, in the appearance of rounded rocks, glacial grooves and moraines, both terminal and lateral.

II. *Leda Clay*. There was a gradual change of level in the sea. At the close of the glacial period the snow line gradually receded from the coast, and the glaciers retreated to the mountains. During the slow and gentle submergence of the land ushering in this epoch, the crude moraine matter was sorted into beds of regularly stratified clays 100 to 300 feet in thickness. The lowest beds consequently are the most ancient, as is also evidenced by the greater prevalence of arctic forms. During this time the sea was filled with floating ice, as at present on the Labrador coast, and the great polar or Labrador current exerted its full power. The temperature being so even throughout the northern hemispheres of the globe, there was a great uniformity in the distribution of life, and certain species enjoyed a wide distribution where now they are restricted to comparatively narrow areas. Toward the close of this period the bison, the Greenland seal, the walrus, and the Vermont whale (*Beluga Vermontana*), flourished. The Age of great Mammals dated from this early period. An arctic fauna and flora inhabited the coast between the sea and the low snow line, and the flora and fauna which are now found only on our alpine heights, or in cold, isolated spots on the coast of Maine and the northern lakes, then peopled the surface of New England and Canada. All the biological features of this epoch partook of an intermixture of the boreal and arctic faunas and floras that are now more distinctly circumscribed into narrower areas.

We have no evidence of an intercontinental communication with Europe during this period. The remains of the bison, the purely American forms of the lower animals found in the Leda clay, all tend to show that no migrations took place either from Europe or Asia into northeastern America. Then, as now, there was a local facies imprinted on those animals whose remains have survived, exhibiting the same faunal distinctions, and even more strongly marked than now.

The close of this period was signalized by a great amelioration of climate, by broad areas of marine clays finely laminated, and having more sand and loam intermixed than in the lowest and oldest beds. This was the transition from a period of broad estuaries, and, at a late stage, of shallow seas, to the next epoch of a secular emergence. It ushered in the —

III. *Period of raised Beaches* (Saxicava Sands). This necessarily implies a great denudation of the glacial clays. The rolled, sea-worn boulders, shingle and sand, composing the mass of the ancient osars and beach deposits, now found at all heights from the present sea-level to 500 or 600 feet, are derived from the resorting of the moraines. We thus find that the highest beaches are the oldest, and the most recent, those just above the ocean level. The temperature of the sea did not differ greatly from that of the present day. During this epoch the present distribution of the faunæ now inhabiting the temperate and arctic zones was established, and since then but little change has taken place. The fresh-water shells found about the Niagara River and other deposits in Canada, were, so far as we know, introduced at this time. Those shells found in beach deposits on the St. Lawrence River, 4–500 feet above the present level of the river, show that but little change has taken place in the climatic relations of the land or in the distribution of the animals depending on such relations. It is evident that the Acadian fauna, once restricted to the regions south of the Saco River, during this epoch crept up the coast of Maine, extended itself along the western shores of the Gulf of St. Lawrence and prevailed in the St. Lawrence River, and the broad estuary now represented by Lake Champlain.

The close of this period witnessed the surface of New England covered by broad lakes and ponds, with vast rivers and extensive estuaries, with deep fiords cutting up the coast-line. Its scenic features must have resembled those of Labrador at the present day.

IV. *The Terrace Epoch.* The estuaries and deep bays left beach deposits of sand and shingle, resulting from the drainage of the slowly rising continent. All the terraces are unconformable to the marine sands underlying them, though the highest terraces farthest from the coast may have been forming while the more recent sea-beaches were being deposited by the action of the waves and tide. Thus the early part of the Lake period is synchronous with the latter part of the Beach period. So also the lower strata of the Leda clays were laid down during the deposition of the oldest beaches, causing a constant inosculation of these unconformable deposits, and thus the beginning of one epoch overlaps the close of the previous one.

II. View of the recent Invertebrate Fauna of Labrador.

The additional observations here recorded were taken from dredging notes made during the summer of 1864, while coasting from the Little Mecatina Island in the Gulf of St. Lawrence, to Hopedale, the lowest Moravian settlement. Many of the localities are known only locally to the fishermen, but their positions relative to points more generally known have been explained in the foregoing part of the article, and are indicated on the geological map.

Note. — I am indebted to Dr. A. A. Gould, Dr. William Stimpson, and Mr. E. S. Morse, for valuable aid in identifying the species mentioned below. The reader will find numerous corrections of typographical errors occurring in an article on the marine invertebrates found at Caribou Island, Straits of Belle Isle, published in the "Canadian Naturalist and Geologist" for December, 1863, and embodied in the present article.

This list is necessarily very imperfect, giving but a slight notion of the riches which must ultimately reward careful exploration in so interesting a field.

Many of the species have been compared with specimens from Greenland received through the kindness of Dr. C. Lütken, Assistant in the Zoölogical Museum of the Royal University of Copenhagen.

Valuable information regarding the identification of several species of Amphipoda has been kindly communicated through Dr. Lütken by Mr. A. Boeck, and similar notes regarding the Polyzoa by Mr. F. A. Smitt, who has detected an alternation of generations among the Polyzoa, some of the asexual forms of which are indicated below.

Polypi.

Metridium marginatum Verrill.

Actinia marginata Say.

This species occurred quite frequently as far north as Square Island in fifteen to thirty fathoms, and Indian Harbor, and in its size and general appearance agreed with specimens dredged at different points on the coast of Maine. The forms when expanded to their fullest extent closely resembled figures of *A. dianthus*, as the disk was subdivided into lobules of a high pinkish color, while in younger specimens the disk was entire, and the polyp was of the usual amber hue. One young specimen when expanded was so transparent that the partitions could all be clearly distinguished, as also the ovaries attached to certain of them. Its disk was elevated above the eight rows of tentacles, each of which had a hyaline, smoky spot at its base.

Rhodactinea (Tealia) Davisii Agass. Verrill. Mem. Bost. Soc. Nat. Hist. I: 18; 1864.

Probably *Tealia crassicornis* Gosse.

Large specimens dredged at Caribou Island in eight fathoms, gravelly bottom, and at Square Island in from fifteen to thirty fathoms on a shelly bottom, had three rows of thick, short, blunt tentacles, each with three red circular bands, the outside of the polyp being entirely smooth with slashes of deep red on a carneous ground. Small specimens were wholly red.

Edwardsia sipunculoides Stimps.

Actinia sipunculoides Stimps. Marine Invertebrates of Grand Menan, p. 7, Pl. I., fig. 2.

A specimen, too imperfect for description, about .75 inch long and .10 inch in diameter, is, according to Professor A. E. Verrill, allied to, or identical with, this species. The tentacles are apparently twenty-four in number. Epidermis destroyed. Four fathoms, Henley Harbor, Chateau Bay.

Hydractinia polyclina Agass.

Hydractinia echinata Stimps. Syn. Inv. Grand Menan.

Found on an ascidian, and also on *Aporrhais,* in fifteen fathoms, Salmon Bay. It occurs along the whole coast.

Coryne mirabilis Agass.

Sarsia mirabilis Agass.[1] *Oceania tubulosa* Gould, Invertebrates of Massachusetts.

This species, just in the act of throwing off the Medusæ, was dredged in great abundance on June 24th, in eight fathoms at Belles Amours, Straits of Belle Isle, where the hydraria were found attached to *Ptilota elegans*, growing on a clean gravelly bottom.

Clava multicornis Pallas.

Clava multicornis Stimps., Leidy. *Clava leptostyla* Agass., Contr. Nat. Hist. U. S.

Occurs on shells in ten to twenty fathoms, Salmon Bay.

Thuiaria thuja Fleming.

Collected by Messrs. Hyatt, Shaler, and Verrill in the Cambridge Expedition to Anticosti in 1861, at the Mingan Islands, Labrador.

Halecium halecinum Johnst.

Caribou Island in eight fathoms, gravelly bottom, where its branches supported the nests of *Cerapus rubricornis* Stimps. Frequent in thirty fathoms; Chateau Bay, on a sandy bottom.

The vesicles are not so urceolate in form, the margin of the mouth being less contracted than Johnston's figures would indicate.

Halecium muricatum Johnst.

Frequent on a fishing-bank off Caribou Island in the Straits of Belle Isle, in from thirty to fifty fathoms. Also common at Square Island a few miles northward of Cape St. Michael, in thirty fathoms.

Cotulina polyzonias Agass. Contr. Nat. Hist. U. S. Vol. IV.

Sertularia polyzonias Linn.

Common between tide-marks at Caribou Island, and in deeper water, where it grows very stout and large.

Cotulina tricuspidata A. Agass. Catalogue of N. Amer. Acalephæ, Mus. Comp. Zoöl. 1865.

Sertularia tricuspidata Alder.

Abundant in the Straits of Belle Isle in forty fathoms upon *Diphasia rosacea*.

Amphitrocha rugosa Agass. Contr. Nat. Hist. U. S.

Sertularia rugosa Linn.

Rarely met with in thirty fathoms at Square Island.

Sertularia filicula Ell. and Sol.

The vesicles are minute, smooth, ovate, pyriform, often subglobose; aperture circular, not produced beyond the body of the cell; seen laterally, it is bidentate.

[1] The synonymy of the Acalephs noticed here is fully given in the Illustrated Catalogue of North American Acalephs in the Museum of Comparative Zoölogy, Cambridge, Mass. By Alex. Agassiz.

Sertularia falcata Linn.

Mingan Island, Gulf of St. Lawrence. Brought home by the Anticosti Expedition.

Sertularia argentea Ell. and Sol.

Caribou Island; not common; found in eight fathoms.

Sertularia cupressina Linn.

The cells in our specimens are large, thick-set; ovicapsules ovate, with fine prominent ribs, while the mouth is round, and much contracted. Henley Harbor, in seven fathoms.

Sertularia abietina Linn.

Mingan Island, Gulf of St. Lawrence, and Labrador. Anticosti Expedition.

Diphasia rosacea Agass.

Sertularia rosacea Linn.

Very abundant in fifty fathoms, gravelly bottom, in the Straits of Belle Isle.

Dynamena pumila Lamx.

Found in abundance in the Straits of Belle Isle between tide-marks.

Lafœa dumosa Sars.

Campanularia dumosa Johnst., 1838.

Cateau Harbor, Long Island; fifteen fathoms; not common.

Cosmetira *sp.*

A beautiful species of this genus, about three inches in diameter, with large tentacles about two inches long and half an inch apart, was found by Mr. Verrill in great abundance, June 25th, at Entry Island, one of the Magdalen Group. Anticosti Expedition.

Laomedea amphora Agass. Contr. Nat. Hist. U. S.

Found on *Bugula murrayana* in fifteen to thirty fathoms; Square Island.

Clytia volubilis A. Agass.

Campanularia volubilis Alder (non Auct.)

Mingan Islands; Anticosti Expedition. Henley Harbor, in deep water, twenty to thirty fathoms.

Oceania languida A Agass.

Campanularia syringa Stimps., Syn. Mar. Invert., Grand Menan.

Caribou Island; dredged at a depth of eight fathoms.

Campanularia verticillata Johnst.

Taken at Henley Harbor, in twenty fathoms of water, upon a pebbly bottom.

Halyclystus auricula Clark.

Very abundant on *Chorda filium,* at low water, August 14th, Anticosti, S. W. Point. Anticosti Expedition.

Lucernaria quadricornis Müll.

Caribou Island, ten fathoms, sand. These two species of Eleutherocarpidæ have been submitted to Professor H. J. Clark for identification.

Manania auricula Clark.

Lucernaria auricula Fabr. (*non* Müll.)

Not common; did not differ from specimens received from the Scandinavian Naturalists.

Trachynema digitale A. Agass.

Medusa digitalis Fabr. Faun. Grönl.

Specimens, agreeing well with Mr. A. Agassiz's figures and description, and of a beautiful sherry tint, were dredged in fifteen fathoms, rocky bottom, near "Strawberry Harbor," and at another point on the coast, southward.

Cyanea arctica Pér. et Lesson.

This species is most commonly observed in the Straits of Belle Isle.

Aurelia flavidula Pér. et Lesson.

Found abundantly in the Straits of Belle Isle, and in retired bays.

Idyia roseola Agass. Contr. Nat. Hist. U. S. 1860.

A very abundant form, and occurring along the coast from Cape Webuc (Harrison) to Salmon Bay in the Straits of Belle Isle, and not differing apparently from specimens observed on the coast of Maine. At Indian Tickle a specimen six inches long was observed. Another specimen was found swimming with its body contracted into the form of a very flattened, oblate sphere, and hence was scarcely recognizable at first sight. The first week in August great numbers of fragments of these animals were observed floating near the surface together with still more abundant wrecks of *Mertensia,* adding greatly to the phosphorescence of the sea, as specimens obtained in the night testified.

Anticosti, Anticosti Expedition.

Pleurobrachia rhododactyla Agass. Mem. Amer. Acad. IV.

Beroe pileus Fabr. Faun. Grönl.

Observed but rarely at Little Mecatina Island, Gulf of St. Lawrence. Anticosti, Anticosti Expedition.

Mertensia ovum Mörch. Bid. til en Besk. af Grönland, 1857.

Beroe ovum Fabr. Faun. Grönl. 1780. *Mertensia cucullus* Agass. Contr. Nat. Hist. U. S. 1860.

This superb species, as fragile as it is beautiful, is of a delicate pink color, with iridescent hues; the bright red spermaries and ovaries, the deep purple, red tentacles being in striking contrast with the delicate tints of the spherosome. As noticed by Mr. A. Agassiz, they are very difficult to keep for more than an hour or so in confinement. This species was extremely abundant from the Straits of Belle Isle, where there was floating ice in the last of June, to as far north as Hopedale in lat. 55° 30′. It was not commonly met with in waters from which the ice had disappeared. It was not noticed by us during our residence in the summer of 1860 at Salmon Bay.

In harbors free from ice the *Mertensia* would keep out of view near the bottom; but as soon as the ice drifted in and choked up the harbor, myriads could be seen near the surface, rising and falling between the ice-cakes, gracefully throwing out their tentacles, which were nearly two feet in length, and suddenly withdrawing them when disturbed.

Bolina alata Agass. Mem. Amer. Acad. 1849.

Anticosti; Anticosti Expedition. Not observed any farther northward.

Echinodermata.

Astrophyton eucnemis Müller and Troschel.

Straits of Belle Isle, in eighty fathoms. They are common in eighteen fathoms on a bank off Caribou Island.

Ophiacantha spinulosa Müll. and Trosch.

Straits of Belle Isle, forty fathoms, upon a hard, rocky, shelly bottom.

Amphiura Holbölli Lütken.

Found in fifteen fathoms at Cateau Bay, Long Island, on a sandy bottom.

Ophiopholis aculeata Müller.

Taken along the whole coast at a depth varying from two to fifty fathoms.

Ophioglypha Sarsii Lyman, Cat. Mus. Comp. Zoöl.

Ophiura Sarsii Lütken.

Cateau Bay, Long Island. Of large size, in fifteen fathoms, on a sandy bottom.

Ophioglypha nodosa Lyman.

Ophiura nodosa Lütken.

The most abundant and characteristic species. At Salmon Bay it occurred in the sand at low-water mark, and also in fifty fathoms in patches of sand on a rocky, shelly bottom in the Straits of Belle Isle. In fifteen to thirty fathoms at Square Island; in fifteen fathoms at Cateau Harbor, and thirty fathoms at Chateau Bay.

Crossaster papposa (Linn) Agass.

Salmon Bay, just below low water; not uncommon at Square Island, in fifteen to thirty fathoms.

Solaster endeca (Linn.) Forbes.

Taken with the preceding species at Long Island, Cateau Bay, in fifteen fathoms. Rare.

Cribella oculata Forbes.

Salmon Bay, Straits of Belle Isle, in fifteen fathoms, on a sandy bottom; not common.

Asterias grœnlandicus Steenstr.

Not uncommon at Caribou Island and Square Island in fifteen fathoms.

Asterias vulgaris Stimps. MSS., Verrill, Proc. Bost. Soc. Nat. Hist., 1866, p. 347.

Asteracanthion rubens Müll. and Trosch.

Common just below low-water mark. The largest specimens from eight to ten inches across.

Asterias (Asteracanthion) polaris Müll et Trosch.

Occurring with, and as common as, the preceding, if not more so. Often taken at Caribou Island, especially the young, in from ten to fifteen fathoms; Square Island and Hopedale.

Asterias n. sp.?

Large specimens, measuring 20 inches across, frequently occurred in pools at low-water mark. The color in life was a light greenish hue, mottled with reddish brown.

Euryechinus dröbachiensis Verrill, Proc. Bost. Soc. 1866, p. 340.

Toxopneustes dröbachiensis Agass. *E. granulatus* Say.

Specimens measuring four inches across were often taken at low-water mark. It extends to fifty fathoms, at which depth it was frequently dredged on the Bank in the Straits of Belle Isle, where the specimens were uniformly small: but after a careful study I cannot see any permanent specific differences. I cannot see that it differs at all from individuals collected during the past summer at Eastport.

Echinarachnius parma Gray.

E. atlanticus Gray.

Abundant and large on sandy bottoms in from two to fifteen fathoms; Straits of Belle Isle.

Lophothuria Fabricii Verrill, l. c., p. 354.

Psolus Fabricii Lütken.

Two were taken in fifteen fathoms on pebbles in Esquimaux Bay.

Pentacta calcigera Stimps.

Cucumaria Koreni Lütken.

One was taken in fifteen fathoms, sand, in Salmon Bay; common at Belles Amours in eight fathoms, mud; Cateau Harbor, fifteen fathoms, sand.

Pentacta frondosa Jaeger.

One specimen was thrown upon the beach.

Chirodota læve Grube.

Very fine specimens, eight inches long, were abundant in ten fathoms, sand, in Salmon Bay; abundant on the whole coast.

Eupyrgus scaber Lütken.

Several were taken in ten fathoms, sand, in Salmon Bay. It has not occurred so low down the coast before. Also at Long Island in fifteen fathoms.

Myriotrochus Rinkii Steenstr. Lütken, Oversigt Grönl. Echinodermer.

This beautiful species first occurred in abundance in patches of sand on a stony bottom in seven fathoms at the anchorage in Domino Harbor. It was afterward found commonly in fifteen to thirty fathoms at Square Island; also at Thomas Bay, fifteen fathoms, sand; Long Island, Sandwich Bay, fifteen fathoms, sand.

Polyzoa.

Tubulipora serpens Johnston.

Occurred in long, twisted masses on *Bugula Murrayana* at Square Island in thirty fathoms; Henley Harbor, common. I have compared this with specimens from Denmark, from which it scarcely differs.

Tubulipora patina Johnst.

Common. Domino Harbor, seven fathoms.

Tubulipora divisa Stimps. Mar. Invert. Gr. Menan, p. 18.

Not common, Henley Harbor, four fathoms. Mr. Smitt states that this form is "a stage of development of *Pencilletta penicillata* (Gray)."

Tubulipora hispida Johnst.

Frequent on sertularians in fifty fathoms.

Tubulipora palmata Wood. (*fide* Smitt.[1])

T. flabellaris Johnst.

On stones in the Straits of Belle Isle, fifty fathoms.

Diastopora verrucaria M. Edw.

Millepora verrucaria O. Fabr.

Frequent in fifty fathoms. I have specimens from Greenland, and also from the Bay of Fundy, from which it does not differ.

Stomapora expansa Packard, Can. Nat., p. 406, 1863.

Creeping, flat, expanding; the branches widening at the origin of new ones, rugose. Cells in the young long, slender, erect, slightly recurved; arising singly, or in groups of two or three at irregular intervals along the branch. Old specimens broader, cells horizontal, apertures hardly raised above the surface, emarginated.

[1] Mr. Smitt's identifications are based on specimens from Labrador sent by us to the Zoölogical Museum at Copenhagen.

A small, slender, white species, the erect tubes in the young longer than the width of the branch. It differs from the European *S.* (*Alecto*) *major* in being broader and more expanded.

Idmonea pruinosa Stimps.

Idmonea atlantica Johnst. (*fide* Smitt.)

Frequent on the bank, in the Straits of Belle Isle. Square Island, at a depth of thirty fathoms.

Hippothoa rugosa Stimps.

Hippothoa catenularia Jameson (*fide* Smitt.)

This species was found in abundance.

H. divaricata Lamx?

Hippothoa borealis D'Orb.

Found in abundance in the Straits of Belle Isle and Cateau Harbor.

Hippothoa expansa Dawson.

Frequent in the Straits of Belle Isle. I have also dredged it at Mount Desert, Maine, in fifteen fathoms.

Lepralia annulata O. Fabr.

A group of three cells, with two spines on each side of the distal margin, occurred in the Straits of Belle Isle; also in Cateau Harbor, Long Island, in fifteen fathoms.

L. crassispina Stimps.

Lepralia ciliata Johnst.

This was one of the most abundant species, and occurs on the whole coast in deep water.

Lepralia n. sp.

Allied to *L. trispinosa* Johnst.; very abundant. It is also abundant in Maine, as far south as Portland. According to Mr. Smitt, this is not the European species, with which it has been confounded in our list in the Canadian Naturalist.

Lepralia pertusa Thomps.

I cannot distinguish my specimens by any permanent characters from the British species. It is oval or broad oval, somewhat flattened or convex, punctured somewhat coarsely, with ridges separating the cells, which are arranged in no special order. Aperture round, truncate behind, or with a broad shallow sinus. The ovi-capsules globose, sub-rugose, sub-punctate, much as in the British specimens. Found growing in purple patches. Length $\frac{1}{30}$ of an inch, half as broad as long.

What I take to be a second and larger form of this species has the cells large, oblong, oval, convex, being closely connected with the ones before and behind in radiating lines. The surface has coarse emarginated punctures. In old specimens the punctures are so large that the surface is often but a net-work enclosing them. Apertures round, slightly raised, with a deep narrow sinus, at the entrance of which are two denticles, one on each side, which often become obsolete. In some cells the surface is perfectly smooth, and only the marginal punctures are present. It is much larger than the preceding form, being $\frac{1}{20}$ of an inch long, and arranged in more regular rows, and preserves better its oblong, oval, convex form. The ovi-capsules are emarginato-punctate, and proportionally smaller and smoother than in the preceding form. Specimens from Greenland do not differ. Long Island, Cateau Harbor, fifteen fathoms. Are the two forms an instance of Dimorphism ?

I have also specimens on *Pecten islandicus* from the Newfoundland Bank.

Mr. Smitt supposes this to be the "Lepralia" stage of *Eschara saccata?*

L. producta Pack. Can. Nat. p. 407, Pl. I., fig. 1.

Cells oval, convex, coarsely punctate; in the young the punctures are emarginate, the base of the cell is produced and wedged in between adjacent ones. Aperture broad, round, with a moderately large and deep sinus in the young; in older cells, small, round, truncate behind, horse-shoe shaped; margin full, broad, unarmed, and when the cells are crowded, the margin in front expanding upon the base of the cell in front. Cells arranged in lines, soon becoming very irregular, and partially radiating; forming white, but more generally purple, patches. Length $\frac{1}{30}$ of an inch. Old specimens are flattened, granulated, with marginal punctures; very rarely the aperture has a small sinus. It is the largest species observed. Frequent.

As in the preceding species, there are two forms which might easily be mistaken for as many species. The young cells are rounded, ovate, depressed, and with emarginate punctures, while the apertures are sinuate. With the other form the species becomes the largest of the genus yet observed on this coast. The cells are much thickened, convex, in outline often pyriform, owing to the elongation of the base of the cell; and the aperture is small and truncate behind.

In both forms the surface is more than usually rugose.

Lepralia trispinosa Johnst. (*fide* Smitt.)

See the remarks under *Eschara lobata* Lamx?

Lepralia Belli Dawson.

Taken frequently on the Bank in the Straits of Belle Isle.

Lepralia labiata Stimps.

Only one group of this singular species occurred.

Lepralia lineata Hassell.

This species was met with but rarely.

Lepralia globifera Pack. Can. Nat. p. 408.

Cells large, flat, white, the surface somewhat raised around the small round aperture, which has a slight sinus. Behind the sinus is a minute perforated conical avicularium. Ovi-cell large, globose, with a few emarginated coarse punctures. Cells in radiating lines, with ridges running between them. The ovi-capsules are more crowded in the centre of the patch, not being present in the inner cells. Frequent, forming frosty white patches. It often encrusts Celleporæ, where the ovi-cells are much crowded, and the ridges between the radiating rows of cells obsolete. I have dredged it in the Bay of Fundy.

Stimpson's *L. candida,* very common in the Bay of Fundy, did not occur in my collection.

Membranipora pilosa Johnst.

Especially abundant encircling fronds of Desmarestia just below low-water mark.

Membranipora lineata Busk.

Frequent in from ten to fifty fathoms, Straits of Belle Isle.

Membranipora (Reptoflustrella) americana D'Orb. (*fide* Smitt.)

M. Lacroixii Busk ? Packard, Can. Nat. p. 408.

I cannot distinguish these two species from Greenland specimens.

Membranipora solida Pack. l. c. p. 408. Pl. I., fig. 2.

Cells large, flat, solid, oval, angulated, often presenting a six-sided figure as is common in the genus. Margin raised, simple, very broad and without spines. Aperture occupying one half of the upper surface, transversely broad, oval, with a broad deep sinus; the posterior half of the upper valve is thin, convex, subrugose, with a small, triangularly perforate, conical avicularium, situated at the posterior end of the upper surface. Cells arranged in lines, or in quincunces, or more often irregularly. The cells are not so crowded as in the other species. To the naked eye it looks like bleached patches of old worn Lepraliæ.

Beania admiranda Pack. l. c. p. 408.

Cells very large, erect, oval, smooth, base produced, sessile. Growing in tufts, the cells arranged in contiguous series, the new cells arising on each side of the aperture of the parent cell. Aperture raised, circular, surmounted by two long, stout, truncate spines, which are succeeded on the opposite side by two rows of long obtuse spines nearly meeting across the hollow formed by the two ridges on the back of the cell. Compared with *B. mirabilis* of the British coast, this is a much stouter species, growing in low spreading, but not creeping, tufts. There are from six to eight pairs of large obtuse spines which meet across the cell; being fewer in number, and longer and stouter than in *B. mirabilis.* More important differences exist in the diameter of the cell which is greatest at the distal or anterior third of the cell, where in the British species it is thickest posteriorly; and in our species the aperture opens near the end of the cell. It occurred rarely on Pecten in fifty fathoms, Straits of Belle Isle.

Crisia eburnea (Linn.)

Crisia luxata Fleming.

Our specimens agree perfectly with Smitt's excellent drawings of the cœnœcium and ovi-cells. Hopedale, ten fathoms, rocky bottom; Henley Harbor, four fathoms.

Cellularia Peachii Johnst ?

Found with the preceding. A rare species.

Menipea ternata Busk?

Rare. Straits of Belle Isle, fifty fathoms. Caribou Island, eight fathoms.

Menipea fruticosa Pack. l. c. p. 409, Pl. I., fig. 3.

This fine species grows an inch in height, with large wide branches, dividing dichotomously. The cells are large and long, being attenuated downwards. Above they are truncated, with four spines, two upon each side, and invariably with an outer projecting spine, when the others are absent. The upper valve is long, oval, and sunken; aperture transversely linear, closed by a square incomplete lid. Cells contiguous, arranged in two alternating rows, with two or three median ones before the origin of the branches. The avicularia have long beaks, and are arranged sparsely at the base of the median cells. Long vibracula arise near the front of a few lower valves. The ovi-capsules are globose and smooth. It is more nearly allied to *M. cirrata* of Europe than to any other species, though very distinct. It is a common species, and occurs in Greenland, from whence I have a specimen.

Scrupocellaria americana Pack. l. c. p. 409.

This species is closely allied to *S. scruposa*, with specimens of which, collected by Dr. Stimpson on the English coast, I have compared it. With much the same habit, our species is twice as large and much more solid. There are the same relative proportions in the form and size of the cells, but in our species the avicularia are smaller in proportion to the cell, and there is but a single spine surmounting this appendage, the lip of the orifice being unarmed, while in *S. scruposa* two spines are very constantly present on the inner side of the cell. The lids or upper valves, which in my specimens are raised from the cœnœcium by the relaxation of the muscles, are convex, and somewhat rugose, owing to several slight transverse lines. The ovi-cells are smooth and globose. It is not infrequent on the Bank in the Straits of Belle Isle. Belles Amours, eight fathoms; Square Island, ten to thirty fathoms. Common.

Acamarchis plumosa Busk.

A. fastigiata (Fabr.) Faun. Grönl.

Thomas Bay, at a depth of fifteen fathoms, in sand and mud. Rare.

Caberea Hookeri Busk.

Our specimens present some differences from the British specimens in my possession, collected by Dr. Stimpson; and also from Mr. Busk's figures. It is abundant in Labrador, and on the coast of Maine as far as Casco Bay. Mr. Smitt pronounces our form identical with the European.

Halophila borealis Pack. l. c. p. 409, Pl. I., fig. 4.

This species agrees well in its generic character with *H. Johnstoniæ* Gray, from New Zealand, though differing specifically, among other respects, in being multiserial. The cœnœcium forms soft and flexible, horn-colored tufts, an inch in height. The cells in mature specimens are arranged in several contiguous series, and are very long, sub-clavate, truncate, widening a little above, with sometimes a slight spine on the outer angle. The aperture is transversely linear and closed by a slightly sinuate lid. The ovi-capsules are globular and nearly smooth. The upper valves are so thin that in dried specimens they readily contract, and the lid and linear aperture are effaced, and the cell then appears as if it possessed a large, broad, oval aperture, covered by a thin lid. A single branch consisted in one example of eight rows of cells. A single isolated cell closely resembles a cell of *Flustra truncata*, showing the near relationship of this genus to the Flustradæ. But one tuft of this interesting species occurred in fifty fathoms, associated with *Beania admiranda*, on a fragment of *Pecten islandicus*, Straits of Belle Isle.

Flustra truncata Linn.

This species was taken frequently.

F. membranacea Linn.

This species was found in abundance.

Flustra digitata n. sp. [Plate VII., fig. 16.]

Cœnœcium broad, rather thick, flexible, membranaceous, dividing into digitate portions, much as in *Bugula Murrayana*. Cells long and narrow, unarmed, well rounded in front. Lid covering a curvilinear aperture opening very near the front edge.

Its unarmed cells, well rounded in front, with the curvilinear aperture, will serve to distinguish it.

Chateau Bay, thirty fathoms. Not uncommon.

Bugula Murrayana Busk.

Abundant on the whole coast. Caribou Island, ten to fifty fathoms; Belles Amours, eight fathoms; Strawberry Harbor, fourteen fathoms; Square Island, ten to thirty fathoms; Domino Harbor, seven fathoms; Hopedale, ten fathoms.

Cellepora pumicosa Ellis.

Found frequently on sertularians.

Celleporaria surcularis Pack. l. c. p. 410.

Grows two or three inches high, branching dichotomously, the ends of the branches somewhat truncated. Cylindrical, base two or three lines in thickness, surface rough. Cells crowded, of unequal size, erect, conical. Aperture small with a slight sinus. In the young conical communities, the cells stand out more from the axis; apertures large, round, with a slight, often obsolete, sinus. Surface of the cells coarse, irregular, and deeply punctured, often arranged in irregular series running down the sides from the aperture. The terminal cell large and conical. In old species the sinus is sometimes enlarged with two denticles at its entrance. In section, the cells are irregularly oval, scattered thickly over the axis and periphery. Abundant on stems and shells in company with Escharæ.

Dr. Stimpson has placed in my hand specimens belonging to this species, collected by Dr. Hayes in Northern Greenland, and by McAndrew in Manseroe Sound, Finmark. European authors have confounded this arctic species with *C. cervicornis* of the Mediterranean Sea, from whence it was originally described by Pallas.

Eschara lobata Lamx ?

Lamouroux describes *Eschara lobata* as growing in radiating patches, always adhering to the surface of objects, and as having been collected near the Banks of Newfoundland.

The cells are oblong, oval, convex; each end is connected with the cell in front and behind, with a few larger emarginate punctures. Aperture round, with a shallow broad sinus. Just behind the aperture a small perforated conical eminence, which in old specimens bears a large avicularium, with long, sharp-pointed beaks gaping widely; or when absent the cone is large, covering the upper surface of the cell, and furrowed with descending ridges. In communities with ovi-capsules, the surface of the cell itself cannot be seen; the capsules are globular, sublunate in form, with emarginated punctures; the aperture large, often truncate behind. Cells arranged in linear series with intervening ridges.

Occurs spreading over dead Cardium and Serripes in ten to twenty fathoms, Salmon Bay, or in fifty fathoms on the Banks; Hopedale, ten fathoms, rocky. I have taken it in the Bay of Fundy and at Eastport from low-water mark to twenty fathoms. Mr. Smitt considers this as being the Lepralia stage, *L. trispinosa*, of an unknown species of Eschara.

It is very different from a thin, flat, membranaceous, inverted, cup-shaped species that inhabits Massachusetts Bay.

E. elegantula D'Orb.

The cœnœcium of this fine species grows several inches high in erect branching masses, the branches expanding flat and spreading at the ends. Cells broad, oval, flattened, somewhat produced at the base; surface smooth, sub-granulated. Aperture round, with a broad shallow sinus. Young cells often margined with a row of large punctures. In old communities the ovi-cells are narrow-oblong, very convex, semi-cylindrical, the cylinder-like avicularia projecting over the aperture, and perforated with a large operculated aperture. Toward the end of the branches, the cells are somewhat cylindrical, bearing narrow globular ovi-capsules, which are emarginate-punctured. This is near Busk's *E. saccata*, which came either from Norway or Finmark. It differs, however, from his figure; and his rather unsatisfactory description does not aid me in determining the species.

Common on the Bank in the Straits of Belle Isle, in company with Cellepora. I have specimens also from the Newfoundland Banks. Dr. Stimpson has also specimens collected in Northern Greenland by Dr. Hayes in his last expedition.

Eschara papposa n. sp. [Plate VII., fig. 17.]

Cœnœcium thick and solid, spreading out in broad, lobulate expansions. Cells numerous, rather small; their surface mostly concealed by the large cylindrical tubes which are unusually erect, giving a papillose appearance to the surface of the cœnœcium; the tube is perforated by a large operculated aperture, which is bilobate orbicular, divided by a mesial obtuse tooth in the hinder edge. The aperture of the cell seen from above is partially concealed by the tube, giving it a lunate form. The ovi-cell is of medium size, globular, thin, smooth and hyaline. The youngest cells at the outer edge of the cœnœcium consist of the very free erect tube, without any ovi-sacs, and with the small aperture protected by a thin lid. The avicularia are remarkably large and thorn-like, being acutely conical, compressed laterally; the smaller lid is often narrow and hooked like a hawk's bill. They occur on the oldest cells. Chateau Bay, not unfrequently found with *Flustra digitata.*

Myriozoum subgracile D'Orb.

Millepora truncata Linn. Fabr., Faun Grönl.

Frequent with the other species.

Fabricius's description applies well to this species. It grows two or three inches high, branching dichotomously; branches cylindrical, smooth, while at irregular distances slightly contracting, — *passim annulis angustioribus* — cells immersed; apertures round with a very narrow, deep sinus, those at the end of the truncate branches have the *figuram calcei equini,* of Fabricius's description. The surface between the cells is deeply and irregularly punctured. A transverse section of a branch shows about twelve oval cells separated by thin walls, arranged around the solid axis of the stem.

This species approaches somewhat Busk's *Eschara teres,* (Ann. Nat. Hist., 1856,) but it seems to have a more regular form; the oval cells shown in a transverse section are not so much produced toward the central axis of the stem; while it differs wholly from *E. teres* in the punctures dotting thickly the whole surface between the cells, instead of there being a single row surrounding the aperture, as usual in the genus. *Millepora truncata* is a Mediterranean species, and, as represented by Lamouroux, is a much larger and very different form from the two species above mentioned. On the Bank in fifty fathoms, with the preceding species; also from the Banks of Newfoundland, and the Bay of Fundy.

Tunicata.

Leptoclinum sp.

A species of compound ascidian was abundant in somewhat pellucid masses surrounding branches of nullipores in fifteen feet.

Didemnium roseum Sars, Reise i Lofoten og Finmarken, p. 33, 1850.

Colony forming a calcareous, thin, encrusting mass, coriaceous, much expanded, surface finely granulated, being covered densely with round, mammillated bodies. Branchial orifices rudely arranged in quincunces, slightly raised above the surface, formed of six triangular lobes, with the alternating lobes a little unequal in size, composed of three or four granules a little larger than those on the surface generally.

It bears a close resemblance to *Didemnium exaratum* Grube, (Ausflug nach Trieste. Taf. II., fig. 2, 2^a,) but the branchial openings are thicker and the mass thinner and more calcareous in our species. It agrees exactly with Sars's description of *D. roseum,* though it is whitish in alcoholic specimens.

Found frequently encrusting fucoids in masses an inch in diameter, in ten fathoms, Hopedale; and on the whole coast. I have also dredged it at Eastport in twenty fathoms.

Ascidia callosa Stimps. Proc. Bost. Soc. Nat. Hist.

Abundant at the Straits of Belle Isle in forty to fifty fathoms, occurring as on the coast of Maine, but growing to a larger size in masses affording shelter to various worms, Gephyrea and Modiolariæ, and serving as a base of attachment to numerous Hydroids.

Glandula glutinans Möller, Index Mollusc. Grönlandiæ.

Does not differ from specimens thus labelled, from Europe. Henley Harbor, six fathoms, sand.

Cynthia pyriformis Rathke.

This species was not uncommon in the Straits of Belle Isle.

Cynthia condylomata n. sp.

Test spherico-conical, surmounted by a spinulated apex ; it is a little higher than broad, with transverse rows of lighter-colored, unequal, wart-like tubercles, which often terminate in minute, blunt spinules, the larger ones stout and curved, with black tips. Apex of the test high, rising up between the two orifices, into a square, truncate, corneous projection, and terminating in five or six large spines. Incurrent and excurrent orifices, consisting of four triangular depressed valves, being surrounded by a raised broad rim of crowded tubercles, surmounted by spinules. Length, .50 inch. A still larger specimen, over an inch in length, from the Banks of Newfoundland, is in the Museum of the Essex Institute.

This species may be easily recognized by its conical form, with circles of large wart-like tubercles, and the steeple-like corneous apex, truncated at tip, and armed with acute, short thick spinules.

Caribou Island, eight fathoms, on Nullipores.

Cynthia echinata (Linn.)

Dredged at a depth of fifty fathoms in Chateau Bay.

Cynthia placenta n. sp.

Test broad, expanded, much flattened, very emarginate, about five times as broad as high, with the thin edge uneven, revolute ; surface granulated, though the scales are flattened. Anal and branchial orifices much alike, of equal height, and as distant from each other as the thickness of the test, which is half an inch in diameter.

One specimen covered with sand was larger and more roughened about the orifices than the other specimen, which was smooth and naked.

Dredged in the Straits of Belle Isle, forty fathoms, hard bottom ; Henley Harbor, ten to twenty fathoms, sandy ; Cateau Harbor, Long Island, fifteen fathoms, sandy. It is also common in the Bay of Fundy.

Pelonaia arenifera Stimps.

This occurred in fifteen fathoms, sand, at Salmon Bay, in the Straits of Belle Isle.

Boltenia Bolteni Linn.

Boltenia oviformis Sav. Pack. Can. Nat. 1863.

Comparison with specimens from Greenland shows that this common species is found along our northeastern coast from the Bay of Fundy to Greenland.

Branchiopoda.

Hypothyris psittacea King.

Frequent on hard and sandy bottoms along the whole coast in from eight to fifty fathoms.

Lamellibranchiata.

Anomia ephippium Linn.

Abundant, though small, at Caribou Island, eight fathoms, on Nullipores. Square Island, thirty fathoms.

Anomia aculeata Gmelin.

Dredged at depths varying from ten to fifty fathoms, Straits of Belle Isle.

Astarte Banksii Leach.

Astarte Laurentiana Lyell, Travels in North America. *Astarte Warhami* Hancock, Ann. Nat. Hist. 1846. *Astarte compressa* Dawson, Can. Nat. *passim.*

There are the same variations noticeable in the fossil specimens from Portland, — which I have received in large numbers from Messrs. E. S. Morse and C. B. Fuller, — as in the recent specimens dredged on the coast of Labrador. Some old specimens resemble the variety *A. Richardsoni* and *A. fabula* of Reeve; others the *A. Warhami* of Hancock; while still older individuals are much eroded at the beaks, as in the recent ones, and much thickened at the hinge. Younger, thinner shells represent *A. Laurentiana* of the St. Lawrence Leda Clays, and agree very closely with specimens thus labelled and kindly sent me by Dr. J. W. Dawson. Recent specimens, given me by Dr. Stimpson from off Halifax, agree very closely with *A. Laurentiana.*

Astarte compressa (Linn.)

Astarte semisulcata Leach. *A. elliptica* Brown, Gould.

Abundant on the whole coast in from ten to fifty fathoms. It is more abundant in the bays than *A. Banksii*, which is a deep-sea shell, and is found on the more exposed deep-sea bottoms.

Astarte striata Leach.

This species was taken at Hopedale in ten fathoms. It is not common.

Cardium islandicum Chemn.

Of large size. In thirty fathoms at Square Island; at Salmon Bay in ten fathoms, mud.

Cardium Hayesii Stimps. Proc. Acad. Nat. Sc. Phil., p. 58, 1862, [Pl. VII., fig. 14.]

This species is found on the whole coast, and is more abundant than the preceding species. Square Island, fifteen to thirty fathoms. Hopedale, ten fathoms. The figure is from a photograph taken by Professor A. E. Verrill, and reduced in size from a specimen nearly three inches long.

Pecten tenuicostatus Mighl.

P. magellanicus Lamk.

Is most abundant on a sandy bottom at a fathom's depth. The young were only dredged in fifteen fathoms. The inhabitants call them "pussels," and often eat them. We can bear testimony to the delicacy and rich flavor of this shell-fish.

A species of boring sponge, *Clionea?* which grows two inches or more in height, its roots boring worm-like galleries in the shell, hastens the decomposition of dead shells very greatly.

Pecten islandicus Müll.

Common in ten to fifty fathoms on a sandy or rocky hard bottom. Valves are occasionally thrown up on beaches.

Limatula sulculus Leach.

Several were dredged in fifteen to fifty fathoms upon a sandy and gravelly bottom.

Nucula tenuis Turton.

Common on the whole coast on a muddy bottom.

Nucula expansa Reeve.

This species occurred abundantly with the preceding. Dr. Stimpson has identified our specimens as being this before doubtful species. Chateau Bay, fifty fathoms, where it occurred of large size.

Yoldia sapotilla Stimps.

A few of these occurred at a depth of ten to fifteen fathoms.

Leda buccata Stimps.

Abundant. Does not differ from Greenland specimens. Long Island, fifteen fathoms; Henley Harbor, twenty fathoms.

Leda minuta (Fabr.)

Long Island, fifteen fathoms; Henley Harbor, twenty fathoms; Chateau Bay, fifty fathoms; Square Island, thirty fathoms.

Crenella glandula Turton.

Abundant. Caribou Island in five fathoms, sandy bottom. Square Island, thirty fathoms.

Modiolaria corrugata Stimps.

This species was found at a depth of fifty fathoms.

Modiolaria lævigata Gray.

This species was taken with the preceding.

Modiolaria faba Fabr.

Henley Harbor, four fathoms.

Modiolaria discrepans Mull.

A valve two inches long was taken from the stomach of a cod caught on the Bank, in the Straits of Belle Isle. Thirty fathoms, Square Island.

Mytilus modiolus Linn.

This species was not common.

Mytilus edulis Linn.

This species was found in great abundance.

Alasmodonta arcuata Barnes?

I was told that a fresh-water mussel was common in Salmon River. This must be the same shell that Professor P. A. Chadbourne informs me is very abundant in the streams of Newfoundland.

Pisidium Steenbuchii (Möll.)

Abundant in fresh-water streams and swampy land at Square Island and Strawberry Harbor.

Cryptodon Gouldii Phil.

Very large and abundant; a few in fifty fathoms, Straits of Belle Isle. Long Island, fifteen fathoms. Chateau Bay, fifty fathoms.

Cardita borealis Conr.

On a bank in fifty fathoms, Straits of Belle Isle. Long Island, fifteen fathoms. Chateau Bay, fifty fathoms.

Cardium pinnulatum Conr.

Very common, and as large as usual southward. It did not occur north of the Straits of Belle Isle.

Serripes grœnlandicus Beck.

This is a very abundant species, and is a very constant companion of *Cardium islandicum*, occurring in a mixed sand and mud bottom in ten to twenty fathoms, where it grows to an enormous size.

It varies considerably when old, some specimens being triangular and flattened, with the beaks placed far anteriorly, while other shells are ventricose, oval, with the beaks very central. The young all agree in being short and high, very thick, and in having the large, swollen beaks placed nearly in the middle of the shells. Some specimens from Greenland differ very much from the Labrador shells in being very triangular, not much longer than high, and having the beaks small and flattened, and placed far anteriorly. Were there not others approaching very closely to some Labrador forms, these characters would easily separate the *grœnlandicus* into two representative species. Whole coast; Square Island, ten to fifty fathoms; Long Island, thirty fathoms.

Gemma Totteni Stimps.

Venus gemma Totten.

Taken in Indian Harbor, low water.

Tapes fluctuosa Sowb.

One valve from the Bank. Henley Harbor, twenty fathoms; Square Island, thirty fathoms. Not uncommon.

Mactra solidissima Chemn.

One valve was given me, which was taken three miles inland from the mouth of Esquimaux River on a sand beach.

Mactra polynema Stimps.

Mactra ovalis Gould.

This species was found rarely having been thrown up on beaches.

Mesodesma Jauresii Joannis.

It is of a very large size, and thrown up very abundantly on beaches.

Macoma fusca Stimps.

It is quite common, generally occurring between tide marks.

Macoma sabulosa Stimps.

T. proxima.

A very large and abundant species, taken in fifteen fathoms, at Salmon Bay; Long Island.

Solenensis Linn.

Rarely taken. Some young specimens were dredged at a depth of fifteen fathoms.

Thracia Conradi Couth.

We succeeded in dredging only one small specimen of this shell.

Thracia myopsis Beck.

A fine large specimen was dredged in ten fathoms mud, at Salmon Bay; at Long Island, in fifteen fathoms, sand.

Anatina papyracea Say.

In fifteen fathoms, sandy bottom, at Chateau Bay. It was identified by Dr. A. A. Gould.

Pandora trilineata Say.

A few specimens occurred in fifteen fathoms, sand. Henley Harbor, twenty fathoms; Square Island, thirty fathoms.

Pandorina arenosa Möll.

One valve was taken with the preceding among nullipores in stony sand, fifteen fathoms. Long Island, fifteen fathoms, sand.

Cyrtodaria siliqua Daudin.

At a depth varying from fifteen to fifty fathoms. Mostly on hard, stony bottoms.

Mya truncata Linn.

The short, obliquely truncated variety *uddevallensis*, occurred on the Bank, and abundantly in thirty fathoms at Square Island.

Mya arenaria Linn.

This species occurred in great abundance.

Saxicava rugosa Linn.

Common in ten to fifty fathoms. Limestone pebbles are often fished up from the Gulf, which are bored into in every direction by these shells, which are then short and much thickened.

Gasteropoda.

Clione limacina Phipps.

Clio borealis Brug.

This species was frequently seen floating near the surface of the water in calm weather.

Limacina helicina Phipps.

This species was taken very abundantly off Cape Harrison.

Proctoporia ? sp.

A species with an expanded foot was taken in fifty fathoms on the Bank. It was not discovered until immersed in alcohol, and is undistinguishable, though it differs from any form known to us to occur in New England, approaching rather Fabricius's figure of *P. fusca*. No other species of Nudibranchs were found, though the ova frequently occurred in round masses on sea-weeds in the *Laminarian* zone.

Eolis sp.

A fine specimen one and a quarter inches long occurred at Henley Harbor, in four fathoms. It is rather broad, slightly flattened, with a broad space between the papillæ. The tentacles are nearly equal in length, the anterior pair remote, the lateral pair recurved, while the posterior pair are of the same length but slenderer, and approximate on each side of the median line of the body. The dorsal papillæ are massed continuously on the sides of the body, four deep in the middle, slightly roseate, with the central biliary (?) tube deep red; tip white; tentacles and body white, with a very faint roseate hue.

Dendronotus arborescens FABR.

Several at a depth of four fathoms in Henley Harbor.

Cylichna alba LOVÉN.

Several large specimens with a thin brown epidermis, and differing in no respect from one from Greenland, occurred in ten to fifteen fathoms, mud and sand; Caribou Island, Chateau Bay fifty fathoms. Sloop Harbor, seven fathoms, sand.

Bulla pertenius MIGH.

This species was taken in the vicinity of Belles Amours, in eight fathoms, muddy bottom.

Bulla occulta MIGH.

Bulla scalpta Reeve, non Belcher.

Chiton marmoreus FABR.

Found all the way from low water to a depth of fifty fathoms.

Chiton albus LINN.

Several specimens of this shell were dredged in fifty fathoms of water.

Tectura testudinalis MÜLL.

This occurs largest and most abundant at low-water mark. The young were dredged in fifteen fathoms.

Pilidium rubellum (FABR.)

Square Island, in thirty fathoms on a hard bottom; near Strawberry Harbor, in twenty fathoms.

Diadora noachina GRAY.

Several specimens taken at the Straits of Belle Isle in ten to fifty fathoms; at Square Island in thirty fathoms.

Scissurella crispata FLEM.

Dr. Dawson has detected this species in sands examined for Foraminifera, as also the following species.

Adeorbis costulata STIMPS.

Both this and the preceding species occurred at Caribou Island.

Margarita cinerea GOULD.

Grows largest on sandy bottom in fifty fathoms. Caribou Island, seven fathoms, hard bottom. Long Island, fifteen fathoms. Square Island, thirty fathoms.

Margarita undulata Sowb. and Brod.

Of common occurrence at a depth of fifteen to twenty fathoms; sandy bottom.

Margarita varicosa Michels.

Found abundantly along the whole coast. At Square Island in ten to thirty fathoms. Straits of Belle Isle, fifty fathoms.

Margarita helicina Möll.

This species was very plentifully found at a depth varying from two to fifteen fathoms.

Margarita campanulata Morse nov. sp. [Pl. VII. fig. 15, 15a.]

Shell umbilicated, depressed, thin, translucent, smooth and shining; composed of four volutions, last whorl rapidly expanding. Aperture large, outer lip flaring. Plane of aperture nearly at a right angle with the axis of the shell; breadth one-sixth of an inch; height one-twelfth of an inch. This species has always been confounded with *Margarita helicina,* which it somewhat resembles. The differences are seen in its smaller size, in its greater depression, and the rapidly expanding outer whorl and flaring aperture. We have examined hundreds of specimens from Portland Harbor and various points on the coast of Maine, and have seen specimens from Labrador, and the characters hold good in every specimen. The color of the extended animal is different from that of *Margarita helicina.* — Morse.

Rissoa minuta Stimps.

One dead specimen occurred; it was found above high-water mark.

Rissoa castanea Möll.

Rissoa exarata Stimps.

Dredged at a depth of fifteen fathoms on a sandy bottom.

Velutina haliotoides Müll.

Found not uncommonly in deep water on the whole coast.

Lacuna vincta Turt.

The plain and banded varieties were common. Taken at Square Island in thirty fathoms.

Littorina vestita Gould.

T. vestitus Say; *L. rudis* Gould.

Not uncommon along the whole coast.

Littorina palliata Gould.

Littorina littoralsi, Forbes and Hanl.

Both of these species occurred abundantly and with variations, as in Maine.

Scalaria grœnlandica Perry.

Of this species we were able to obtain only a fragment of a specimen.

Turritella erosa Couth.

Abundant along the whole coast, at Chateau Bay, Long Island, in fifteen fathoms, sand.

Turritella reticulata Mighl.

Very abundant, occurring with the preceding in ten to fifty fathoms, but most abundant in fifteen fathoms, mud, Salmon Bay. Chateau Bay, fifteen fathoms. Square Island, thirty fathoms. Hopedale, ten fathoms.

Turritella acicula Stimps.

One individual of this species was dredged at a depth of fifty fathoms, on a hard bottom.

Aporrhais occidentalis Beck.

Very abundant on the whole coast from Salmon Bay to Hopedale, and is one of the most characteristic shells of the coast, occurring in from six to fifty fathoms, mostly in muddy quiet bays.

Menestho albula Möll.

Young specimens occurred very frequently in from two to fifteen fathoms, sand.

Lamellaria perspicua Lovén.

Dredged at a depth of fifteen fathoms, on a sandy and muddy bottom.

Natica heros Say.

Two young dead shells were found at high-water mark, in Salmon Bay, Straits of Belle Isle.

Natica clausa Sowb.

Found to occur quite frequently at a depth of fifteen fathoms.

Natica (Lunatia) grœnlandica Beck.

Taken at Chateau Bay, Long Island, in fifteen fathoms, on a sandy bottom.

Bela americana.

Defrancia scalaris Möll., Ind. Moll. Grönl. *Fusus turricula* Gould.

The European *B. turricula,* as observed by Mörch, is very different from the American representative. On a comparison of our shell with several specimens of the *turricula,* we find that the shoulder on each whorl which gives the shell its turreted appearance, is situated more in the middle in *B. scalaris.* The *turricula* has twelve longitudinal ridges on each whorl, being fewer and proportionately larger than in our species, which has seventeen. Our species seems also to be a larger shell. It agrees well with Möller's *D. scalaris,* to which he refers *turricula* Gould.

In a long variety figured on Pl. vii. fig. 11, the shell is slender, much elongated, regularly fusiform, whorls flattened more than usual, being but slightly flattened, with the shoulder of each whorl removed much nearer the middle than is usual; spine acute, longer than the body of the shell, suture not deeply impressed; aperture long ovate; columella smooth, a little flattened, regularly concave, not plicated; canal very short, oblique; the body of the shell covered with revolving lines and slightly waved longitudinal plications, which are especially marked on the spine. Length, .48; breadth, .20; length of aperture, .22 inch. One specimen was dredged in fifteen to thirty fathoms at Square Island. Found fossil at Caribou Island; rare. The typical forms are found on the whole coast.

Bela nobilis (Möller).

This species differs from *B. americana and B. turricula* (of which we would scarcely consider it a variety), in its fewer and larger rugæ, with less distinct revolving lines.

Bela scalaris.

Defrancia scalaris Möll., Index Moll. Grönl.

This shell we would consider as also distinct from *B. americana*, and like that species it has both a short and elongated form. The canal is longer and the spine is more acute. The fossil specimens scarcely differ. Specimens from Dr. Lovén, thus labelled, were kindly loaned me by Dr. A. A. Gould for comparison. Square Island, thirty fathoms, shelly bottom; and also at Dumplin Harbor, Sandwich Bay, in four fathoms.

Bela woodiana Möll.

Fusus harpularius Gould.

It is a shorter and thicker shell than the preceding, in which the first whorl is as long as the remaining ones together. Not common, though a very abundant fossil.

Bela exarata.

Defrancia exarata Möller. *Pleurotoma rugulatus* "Möll." Reeve, Icon. Conch. fig. 345.

In this species the first whorl is longer than the rest; the canal is shorter and the aperture rounder. The longitudinal ridges are the same in number as in *B. woodiana*, but are less prominent, while the revolving lines are much coarser, giving the surface a reticulated appearance. Common on the whole coast.

Bela decussata Stimps.

Common in Salmon Bay in ten to fifteen fathom, smud, where it occurred more abundantly than elsewhere on the coast. Square Island in thirty fathoms, shelly bottom.

Bela pleurotomaria Stimps.

Fusus pleurotomarius Couth. *Defrancia Vahlii* Beck.

Dredged at a depth of thirty fathoms Square Island; of four fathoms at Sandwich Bay.

Bela pyrimidalis Stimps.

Fusus rufus Gould.

This species is found along the whole coast. Taken in thirty fathoms, at Square Island.

Bela cancellata Mighl.

Not uncommon at Square Island in thirty fathoms.

We should scarcely unite *B. Pingelii* (Beck) from Greenland, with this form. It differs in the long and slender, scarcely turreted, less convex whorls; the costæ and revolving lines are fainter, and the last are more numerous; the canal is slenderer and more pointed. Reeve's *Fusus rugulatus* Icon. Conch. is perhaps a synonym of *B. Pingelii*, though stated by Mörch to be identical with *B. exarata*.

Bela violacea Stimps.

Common along the whole coast. Dredged at Square Island, in thirty fathoms, on a shelly bottom.

Bela borealis.

Pleurotoma borealis Reeve, l. c. f. 277. *Defrancia livida* Möll. (non Linn.)

This species occurred but rarely. It was found at Square Island in thirty fathoms; at Sandwich Bay in four fathoms.

Buccinum Grœnlandicum Hancock. [Plate VII., fig. 5.]

Buccinum grœnlandicum Hancock, Annals and Mag. Nat. Hist. [1.] xviii., 329; pl. v., figs. 8, 9, 1846. Reeve, Conch. Icon., iii. Bucc. xiv., 118, 1847. *Buccinum Anglicanum* Lyell, Trans. Geol. Soc. *Nitorium Hancockii* Mörch. in Rink's Greenland Taellaeg. Aftr., 84, 1857.

A fine specimen of this species, but belonging to a rather more elongated type than usual, comes from the Banks of Newfoundland, and is in the collection of Mr. C. B. Fuller of Portland, who kindly loaned us two specimens for illustration.

It did not occur to us in a living state on the coast of Labrador, though it will doubtless be found there on more careful search.

A fossil specimen occurred at Pitts Arm, Chateau Bay, with nearly all the outer coating of shell off. It is thick and stout. (Pl. vii. fig. 5 a.) The large single spiral rib is very prominent, while midway between it and the suture are two ribs of half the size.

I have also received a much thinner shell from the Leda clays of Montreal, kindly sent by Dr. J. W. Dawson, associated with *Trichotropis borealis;* also from Negrotown Point, at Carleton, opposite St. John, N. B., collected by Messrs. Mathews and Hartt.

From Canal Street, Portland, specimens collected by Mr. C. B. Fuller are unusually ventricose, more heavily plicated with large costæ, increasing in size nearer the suture than usual, and with a large raised revolving line.

This very rugose form [Pl. vii. fig. 5] also occurred fossil at Caribou Island. Young specimens collected at Portland by Mr. Fuller, however, conform more to the slender type, and agree in all respects with Lyell's figure in the Transactions of the Geological Society.

Buccinum undulatum Möller. [Pl. VII., fig. 3, young; 4, adult.]

Buccinum Labradorense Reeve, Icon. Conch., pl. i. fig. 5.

Most abundant just below low-water mark. Fine specimens three and a half inches long were frequent; their egg capsules laid in large bunches were often deposited at low-water mark. This species represents the European *B. undatum.*

We figure a young specimen dredged in deep water, with a prominent central carina on the lower whorl.

Buccinum tenue Gray. [Pl. VII., fig. 6, fossil.]

B. scalariforme Müll.

One specimen was taken on the Bank, Straits of Belle Isle.

Buccinum cretaceum Reeve, Icon. Conch., Monogr. Bucc., Pl. XIV., fig. 112.

At Long Island, found in fifteen fathoms. Shell fusiform, slender, nearly three times as long as broad. Aperture oval, ending in a rather long, broad, oblique canal. Inner lip regularly curved; the columella projecting into the aperture at the base of the canal; from this projection a slight ridge runs back to the other end of the aperture, following the curve of the inner lip. Whorls nine, convex, especially on the upper two thirds. Spire much prolonged, acute. Twenty-one longitudinal ridges, smooth and rounded. On the first whorl the ridges disappear on the lower two thirds, where the minute revolving lines are more minute than elsewhere. Aperture within light chocolate, darker in the young, in which the revolving lines are more distinct. Length, $\frac{21}{20}$ in., breadth, $\frac{8}{10}$ in.

The slender and fusiform shape, and greater length of the spire than is found in other northern species, will distinguish it. The young and old were dredged alive in ten fathoms, mud and sand, Salmon Bay. Dr. Stimpson informs me that he has seen specimens from the Newfoundland Banks. It seems to be identical with Reeve's species, of which he gives no locality. This fine species is not uncommon, occurring at Caribou Island, seven fathoms young and old, mostly on a rocky bottom. Square Island, fifteen to thirty fathoms, on a shelly bottom.

Fusus (Neptunea) islandicus Gould.

According to Dr. Stimpson our American form differs specifically from the European form. A specimen from the Banks is remarkably short and thick, the spire being no longer than the aperture, while the whorls are flattened, being but slightly convex with no revolving lines. The canal is long and tortuous. Length, 2 inches; breadth, $1\frac{1}{10}$ inches. It did not occur to us on the Labrador coast.

Mörch (Journal de Conchyliologie, 3d Ser. T. II. 36, Pl. I. fig. 1,) describes from Newfoundland a closely allied species, *Fusus* (*Sipho*) *lividus.*

Fusus syrtensis n. sp. [Plate VII., fig. 13.]

Shell thin, very short, ovate; spire rapidly acuminate, cylindrical, broadly conico-fusiform, a little more than one half as long as the rest of the shell. Aperture large ovate; canal remarkably short, oblique, very wide, the aperture contracting less than usual; whorls, especially the first one, with fine revolving lines, becoming larger in the middle of the lower whorl and disappearing toward the suture. Longitudinal costæ eighteen in number on the lowest whorl, becoming more prominent toward the suture; on the second and third whorls they are larger and more contiguous, and waved. Whorls six, much less convex, sutures very shallow.

Length, .40; breadth, .17 inch.

A remarkably short conico-fusiform shell which from its thick, broad canal, resembles a Bela, and in this respect differs from the group *Sipho islandicus*, or *Fusus pullus* of Reeve, from Newfoundland.

One specimen was dredged on a shelly bottom in thirty fathoms, Square Island Harbor.

Fusus tornatus GOULD.

A large specimen, tenanted by a hermit crab, was dredged in fifty fathoms.

Trichotropis borealis BROD. and SOWB.

Taken frequently at a depth varying from ten to fifty fathoms. Long Island, fifteen fathoms; Hopedale, ten fathoms.

Admete viridula STIMPS.

Thick, heavy specimens, an inch in length, were dredged in forty to fifty fathoms.

Trophon scalariforme STIMPS.

Large specimens from the Bank, Straits of Belle Isle; Chateau Bay, fifty fathoms; at Henley Harbor, twenty fathoms.

Isthmia (Pupa) Hoppii BECK.

Common at Strawberry Harbor, in company with the succeeding species. This species with the other land shells, was identified by Mr. E. S. Morse.

Zoögenetes harpa (SAY), MORSE.

One specimen of this was found in moss at Caribou Island.

Conulus (Helix) Fabricii BECK et MÖLLER.

At Strawberry Harbor, July 26. Found under sticks in a retired and protected valley.

Hyalina electrina (SAY).

Common at Belles Amours, in wet, protected places.

Vitrina angelicæ BECK et MÖLLER.

Common, generally occurring with the preceding species. Taken at Strawberry Harbor.

Limax agrestis LINN.

Not uncommon at Strawberry Harbor and at Square Island, under stones.

Besides these shells, the Anticosti Expedition from Cambridge collected at the Mingan Islands *Vitrina angelicæ*, *Succinea obliqua* Say, *Succinea avara* Say, *Succinea Verrillii* Bland, *Pupa badia* Adams, *Zua lubricoides* Stimps., *Helix chersina* Say, *Helix arborea* Say, and *Helix striatella* Anthony.

The only Cephalopod known is the common Squid, *Ommastrephes todarus?*

Vermes.

Syrinx? n. sp. [Plate VIII., fig 10.]

A small slender species occurred in eight fathoms, sandy bottom, at Caribou Island, which is provisionally described here, as no specimens were observed in a living state, and even the genus is doubtful. It is slender, cylindrical, the anterior half of the body gradually increasing in size towards the mouth, where in our alcoholic specimens it is suddenly truncated, or, as in another specimen, this part of the body is swollen into an ovate enlargement and slightly constricted just before the mouth. The surface is very minutely granulated with a delicate peach-like pubescence, and is dull white in spirits; posterior half of the body smooth, being scarcely granulated or striated. Posteriorly the body is suddenly truncated, with a large anal opening. At the mouth are five indistinct lobes, which are probably the retracted tentacles, but there are no traces of any bristles. Length, .35–.40 inch; breadth, .04 inch. Found free in the sand, not inhabiting shells.

Phascolosoma hamulatum n. sp. [Plate VIII., fig. 8.]

Body long, slender, cylindrical, anteriorly finely corrugated transversely with minute granulations; much swollen toward the head, into a large, globose dilatation, which is smoother than the adjacent parts. Mouth surrounded with about twenty short tentacles placed on a neck-like constriction. The posterior part of the body, concealed within a deserted shell, is much longer than the anterior, sac-like, loose, and soft, increasing in width toward the end, surface not wrinkled except at the end, which is suddenly rounded, but covered with flat granular scales; posteriorly the flattened granulations terminate in hard corneous, curved points bent toward the head, which probably act as hooks to retain the animal within its domicile. The mouth of the shell is prolonged by a tube of fine granules of sand, like those of Sabella.

Length, .50 inch; smallest diameter, just posterior to the dilatation behind the head, .04 inch; diameter of the thickest portion of the sac, .10 inch.

But one specimen was taken in eight fathoms, Caribou Island, Straits of Belle Isle, inhabiting a dead shell of *Aporrhais occidentalis*.

This interesting form differs from *Phascolosoma granulatum* F. S. Leuckart, (Brevis animalium quorandam descriptiones, p. 22, fig. 5, 1828,) in its much more elongated body, and in possessing tentacles of which Leuckart's specimens apparently had none, though they may have been withdrawn within the body in the specimen before him. The anterior part of the body of Leuckart's species does not merge so gradually into the posterior sac, and it is thicker at the middle of the body, where in our species the body increases in thickness toward the end.

Gordius lacustris Fabr.? Fauna Grönl.

This species occurred quite frequently in shallow, fresh-water pools.

Pontobdella sp.

A very young specimen was found between tide marks in the Straits of Belle Isle, and a large specimen, afterwards lost, was found attached to the under side of a *Crangon boreas* in four fathoms, Henley Harbor.

Pontobdella? livida nov. sp. [Pl. VIII., fig. 9.]

A large livid, greenish, cylindrical worm, belonging undoubtedly to one a little thicker on the anterior third of the body, gradually tapering to a point anteriorly, and more obtuse posteriorly. The mouth is a single longitudinal narrow slit; the surface is finely and irregularly transversely wrinkled, the sides of each furrow being very regularly and minutely sinuated, the corrugations of unequal length and wedged in between each other. There are no longitudinal lines except on the posterior extremity where the transverse corrugations become longitudinal, and their sides are scarcely sinuate. Toward the mouth the surface is smooth. This specimen was not observed while living, so that the soft retractive ends of the body, which probably would then have been seen, are, if present at all, retracted in spirits. Belles Amours, eight fathoms, mud. Rare.

Cerebratulus (Meckelia) olivacea Rathke, Nova Acta Nat. Cur. xx. 1, 2, 3, 4, p. 237. Diesing, Syst. Helm. i. p. 264.

My specimens agree well with the description of Diesing, which was evidently copied by that author from Rathke's description. His specimens came from Norway. It is olivaceous in hue, and alcoholic specimens are apt to be broken into several sections. Common at Salmon Bay in ten fathoms, deep mud. Belles Amours, eight fathoms, soft mud. Henley Harbor, twenty fathoms.

Cerebratulus cylindricus nov. sp. [Pl. VIII., fig. 11.]

Body long, slender, cylindrical, of uniform width throughout, not tapering toward either end; mouth consisting of a long slit, extending down each side of the conical head; posteriorly the body is flattened from above, downwards. The figure represents the anterior part of the body including the head. One specimen at Belles Amours, in eight fathoms, mud.

Omaloplea Stimpsoni Girard, Stimps. Mar. Inv. Grand Menan.

Taken at Anticosti at a depth of fifteen fathoms, by the Anticosti Expedition.

Lumbricus terrestris Linn.

Small specimens, nearly an inch in length, were found in the peaty soil at Hopedale and Square Island.

Spirorbis vitrea (Fabr.)

Near Strawberry Harbor, in fifteen fathoms, on pebbles. Straits of Belle Isle, in forty to fifty fathoms. Found along the whole coast.

Spirorbis sinistrorsa Montagu.

Common at Henley Harbor, at a depth of four fathoms, on Algae.

Spirorbis porrecta Müll.

Common in ten to thirty fathoms, on Hydroids and Polyzoa. Found along the whole coast.

Spirorbis cuncellata (Fabr.)

Common on the whole coast in deep water. Straits of Belle Isle, in forty fathoms, on a stony bottom.

Spirorbis granulata (Müll.)

Found of large size along the whole coast, in ten to forty fathoms.

Spirorbis spirillum (Linn.)

This species occurs along the whole coast. Found on Fucus.

Vermilia serrula Stimps.

Dredged in the Straits of Belle Isle, at a depth of fifty fathoms.

Amphitrite cirrata Müll.

Terebrella cirrata Montagu, Trans. Linn. Soc. xii.

It constructs its tubes of fine sand. Cateau Harbor, Long Island. Caribou Island, Straits of Belle Isle, eight fathoms, sandy bottom. Common along the whole coast.

Amphitrite ? sp.

A specimen too imperfect for description; has two long fleshy tentaculum-like cirri on the fourth and fifth rings from the head, arising from just behind the uncinæ, which are composed of a single seta, one on each side of the ring. The specimen also wants the usual papilla at the base of the seta.

Ampharete Grubei Malmgren, Nordiska Hafs-Annulater. 363. Pl. XIX., fig. 44.

It constructs a tube, which reminds us of the cases of some Phryganeæ, of bits of seaweeds and sand loosely placed together. The color of alcoholic specimens is livid, with a slight greenish tinge. Length, .50 inches. One specimen agrees well with Malmgren's description, and figures as observed by this author. It is very different from Grube's figure (Wiegmann's Archiv. xxvi. Tab. v. fig. 6), of *Amphicteis acutifrons*, from Greenland. Henley Harbor, in four fathoms; not uncommon.

Cistenides granulata Linn. non Johnst.

Pectinaria grœnlandica Grube.

Occurs along the whole coast. Found in abundance from near low-water mark to fifty fathoms depth.

Praxilla Mülleri MALMG. l. c. p. 191.

Clymene Mulleri Sars, Fauna litt. Nor. II., p. 13. Pl. I., figs. 1–7.

A specimen of the anterior part of the body agrees well with Sars's description, but the head is contracted, and thus not recognizable in alcohol. Chateau Bay, thirty to forty fathoms, in hard sand. Cateau Harbor, Long Island, in fifteen fathoms, sand.

Nicomache lumbricalis MALMG. l. c..

Sabella lumbricalis Fabr. Fauna Grönlandica, 374. *Clymene lumbricalis* Sars, l. c. 16. Tab. II., figs. 23–26.

Caribou Island, eight fathoms, sand. This species constructs its tube of fine sand, a little more than a line in thickness and two and a half inches long.

Another species closely allied to the preceding, forms a much larger tube of sand, which is rolled on itself, in thirty to forty fathoms, Chateau Bay.

Spiochætopteras typicus SARS, l. c. ii. p. 1. Pl. 1., figs. 8–21.

The tubes resemble very closely Sars's figure. On one side is a longitudinal median furrow where the transverse ridges are interrupted. The occurrence of this genus on our coast is interesting. The animal itself was obtained. Chateau Bay, in thirty to forty fathoms, hard sandy bottom. Sars's specimens, from Bergen, Norway, occurred also at the depth of forty fathoms. Several fragments of tubes were also found fossil in the quaternary beds at Caribou Island.

Arenicola piscatorum LAMK.

A specimen was found in the stomach of a codfish, taken in fifteen to twenty fathoms, at Belles Amours.

Siphonostomum asperum STIMPS. l c. p. 31.

Dredged at Caribou Island, in eight fathoms of water, on a sandy bottom.

Siphonostomum plumosum MÜLL. (fide STIMPS.)

This species was found at Salmon Bay, at a depth of ten fathoms, on a muddy bottom.

Cinatulus cirrata (FABR.)

Cinatulus borealis Lamk.

Taken from the stomach of a codfish caught in ten fathoms, Straits of Belle Isle, off Belles Amours.

Heteronereis arctica OËRSTED ?

Quite commonly found swimming on the surface of the water, in harbors.

Nephthys longisetosa OËRSTED. Grönl. Ann. Dorsib. p. 43. Tab. VI., figs. 75, 76.

N. longisetosa Malmg. Nord. Hafs Annulater, p. 106. Tab. XII. fig. 20.

Dredged at Belles Amours, at a depth of five fathoms, on a muddy bottom.

Nephthys cæca Oërsted. l. c. 41, figs. 73, 74, 77, 79–86.

Nephthys cæca Malmg. l. c. p. 104. *Nereis caeca* Fabr. Faun. Grön. p. 304. Tab. xii. 18.

Abundant on the whole coast, especially the young which were dredged in deep, soft mud, in Salmon Bay and Belles Amours in from five to twenty fathoms, and at Cateau Harbor, in fifteen fathoms, sand. Chateau Bay thirty fathoms, hard sandy bottom.

Eteone cylindrica Oërsted, l. c. p. 35, figs. 42–49, 57.

This species was found at Belles Amours in five fathoms of water, on a muddy bottom.

Phyllodice grœnlandica Oërsted. l. c. p. 40, figs. 19, 21, 22, 29, 32.

P. grœnlandica Malmg. l. c. p. 96.

Dredged at Square Island, in fifteen to twenty fathoms, on a shelly bottom. Frequent at Caribou Island in eight fathoms, sand. At Belles Amours in five fathoms, mud.

Onuphis Eschrichtii Oërsted. l. c.

My specimens differ from those received from Greenland, through Dr. Lütken, and labelled *O. Eschrichtii*, in having the tentacular cirri but one half as long as the middle pair especially, and the lateral cirri are much larger and thus more prominent, the posterior cirri especially are much longer, while in the Greenland specimens they are more papilliform. Chateau Bay twenty-five to thirty fathoms. Salmon Bay fifteen fathoms. Cateau Harbor fifteen fathoms, sand.

Nereis pelagica (Linn.) Oërsted. l. c.

Occurs frequently from Anticosti to Square Island, in ten to thirty fathoms.

Nereis sp.

Allied, according to Dr. Stimpson, to *N. denticulata* Stimps. Mar. Inv. Grand Menan, which is common on the coast of Maine between tide marks, Salmon Bay.

Pholoë minuta Oërsted. l. c. p. 169. Tab. I., figs. 3, 4, 8, 9, 16.

A common species at Belles Amours, found in eight fathoms, on a muddy bottom.

Harmothoë imbricata Linn.

Aphrodita imbricata Linn. Syst. Nat. Ed. xii. 1767. *Aphrodita cirrata* Müller. Prodr. Zoöl. Dan. n. 2644. Fabr. Faun. Gröul. p 308, n. 290. Tab. 1, fig. 7. *Lepidonota cirrata* Oërsted. l. c. p. 14, figs. 1, 5, 6, 11, 14, 15. *Harmothoë imbricata* Malmgren, l. c. p. 66. Tab. ix. fig. 8.

Caribou Island eight fathoms, sand. Sloop Harbor six to eight fathoms, sand, common. Cateau Harbor fifteen fathoms, sand. Sandwich Bay at Dumplin Harbor, four fathoms.

This species is very variable in the color of its scales (" elytra "), which in some individuals are uniformly pale, in others partially red, while others have a central spot, and a broad, dark, curved band.

Lepidonotus squatmaus (Linn.)

Aphrodite squamata Linn. Syst. Nat. Ed. x. 655. *Polynoë squamata* Andouin et Milne Edwards. Hist. Nat. Litteral du France, II. 1834. *Aphrodite punctata* Müller, Prodr. Zoölogica Danica. *Lepidonote punctata* Oërsted. l. c. p. 12, figs. 2, 5. 39, 41, 47, 48.

Common along the whole coast. Occurs all the way from low water to twenty fathoms.

Crustacea.

Nymphon grossipes Fabr. Faun. Grönl.

This species was dredged at Salmon Bay and Square Island, in from fifteen to thirty fathoms.

Coronula diadema (Linn.)

Taken quite frequently from the skin of whales caught in the Gulf of St. Lawrence.

Balanus crenatus Brug.

A common species, found along the whole coast.

Balanus balanoides Linn.

Balanus porcatus Da Costa.

This species occurs along the whole coast, and is found only in deep water.

Peltogaster paguri Rathke.

Not as yet found in Labrador, but a specimen has occurred at Eastport, Maine, on *Eupagurus pubcscens,* án arctic crab.

Leonæa branchialis Linn.

Specimens of this animal were found attached to the skin of the codfish.

Daphnia sp.

This is a large species allied to *D. rectispina,* and is found abundantly in all the fresh-water pools.

Cypridina excisa Stimps. l. c. p. 39. Fig. 28.

Branchipus paludosus Müll.

Found abundantly at "Indian Tickle," on the north shore of Invuctoke Inlet, in a pool of fresh water.

Nebalia bipes Fabr.

This species was dredged at Henley Harbor, at a depth of four to eight fathoms.

Bopyrus mysidum nov. sp. [Pl. VIII., fig. 5.]

Body long and narrow, head much rounded; body behind the middle rapidly tapering to a point ending in two short, obtuse, papilla-like stylets. The last three abdominal segments are distinct, those of the middle of the body indistinguishable. Seen laterally it is convex, flattened beneath. The legs are curved, one quarter as thick as long, rapidly thickening toward the head. Length, .09; breadth, .04 inch. A female. It differs from *B. squillarum* Rathke, and *B. hippolytis* Kr., in its much narrower, more linear body, slenderer legs, and in the presence of the caudal stylets. The drawing is a rude one, as the specimen had unfortunately dried before it was finished, but the general contour is given accurately.

Æga sp.

One specimen was taken from the under side of a cod in the Straits of Belle Isle.

Tanais filum Stimps. Marine Invert. Gr. Menan, p. 43.

This specimen was dredged at Caribou Island, in eight fathoms, on a sandy bottom. Rare.

Praniza cerina Stimps. l. c. 42.

Found at Chateau Bay, Long Island, at a depth of fifteen fathoms, on a sandy bottom.

Jæra nivalis Kroyer.

This species is abundant at low water under stones at Indian Harbor, Sandwich Bay.

Asellus grœnlandicus Kroyer.

Specimens agreeing in length with those noticed by Fabricius, Fauna Grönlandica, were common at Square Island and Hopedale, in soil under stones, etc., in company with Limax.

Idotæa marmorata nov. sp. [Pl. VIII., fig. 6.]

A stout, thick, reddish-brown species, with the surface slightly nodulated and marbled; body rather short; head more transverse and shorter than in *I. nodulosa* Kr., not armed with sharp tubercles in front; anterior edge emarginate, acutely rectangular on the sides, with an angulated slight excavation, and a narrow, deep, but small, mesial notch; eyes large and prominent. Superior antennæ of much the same proportions as in *I. nodulosa*, but the joints are thicker. Inferior pair of antennæ long and slender; peduncle stout, with the second joint two thirds as long as the third; flagellum longer than the peduncle, where in *I. nodulosa* they are considerably shorter; each joint terminating in a thin verticil of hairs. Segments of the body convex, on the sides distinctly emarginate; the edges of each segment are straight, not convex as in *I. nodulosa.* Upper surface of the body thick, with short, impressed, broken lines diverging in their general direction from the median line of the body. Abdomen short, thick, mesially very convex; tips truncated, with a sinus at the end. Legs stout, hairy. Color purplish, reddish on the edge of the segments, and the limbs are slightly brownish, in the single alcoholic specimen in the Museum of the Society. Length, .70; breadth, .28 inch.

It differs from specimens of *I. nodulosa* Kr. in its short, thick, convex body having a much more solid, dense crust than any species found southward. The outer edge of the segments are straight, while in *I. nodulosa* they are very convex; and it may also be readily known by the truncated, sinuated tip of the abdomen.

Sloop Harbor, Kyuetarbuck Bay, seven fathoms, on a sandy bottom.

Caprella septentrionalis KROYER.

Squilla lobata Fabr. Faun. Grönl.

Found abundantly along the whole coast, in from four to thirty fathoms, among weeds.

Themisto sp. (*fide* STIMPSON.)

Found at Anticosti. Brought home by the Anticosti Expedition.

Hyperia medusarum BATE, Cat. Amph. Br. Mus. p. 295. Pl. XLIX., fig. 1.

Metœcus medusarum (Fabr.) Kr.

Found with numerous young in the stomach-cavity of *Cyanca arctica*, at Domino Harbor.

Dulichia porrecta (*fide* BOECK).

This is a rarely found species.

Cerapus rubriformis STIMPS. Mar. Inv. Gr. Menan, p. 46.

Inhabits flexible tubes in *Halecium halecina*. Eight fathoms, sand, Caribou Island, Straits of Belle Isle. The young had just been hatched on June 20th.

Amphithœ maculata STIMPS. l. c. 53.

The specimen obtained at Henley Harbor in eight fathoms, is punctured all over the body, forming dorsal bands on the posterior half of the segments. It is punctured irregularly on the epimera and legs, while on the antennæ, especially toward the base, the dots are arranged in rings.

Gammarus locusta (LINN.) LEACH.

Gammarus mutatus Lilljeb.

As usual, this species is found in great abundance along the whole coast.

Gammarus dentatus KROYER.

Gammarus purpuratus Stimps., l. c. p. 55.

A comparison of the European specimens sent by Dr. Lütken, leads us with Mr. Bate to unite these two species. Square Island, fifteen to thirty fathoms; Straits of Belle Isle, fifteen fathoms, mud; Chateau Bay, twenty to thirty fathoms.

Paramphitæ panopla KROYER, Grönland's Amfipoda. (*fide* BOECK.)

This species was rarely met with.

Calliope læviuscula Bate, l. c. p. 148. Pl. XXVIII., fig. 2.

Amphithoë læviuscula Kr., Grönl. Amfip. p. 53, Tab. III., fig. 13.

Found at Henley Harbor, in four fathoms, very abundant; at Stag Bay in fifteen fathoms, on a hard, weedy bottom. Anticosti, Anticosti Expedition.

Amphitonotus Edwardsii Bate, l. c. 151, Pl. XXVIII., fig. 5.

Amphithoë Edwardsii (Sabine) Kr. l. c.

Our specimens were dredged at Square Island, at a depth of thirty fathoms.

Amphitonotus cataphractus Stimps. l. c. p. 52.

Taken at Henley Harbor, at a depth of four fathoms, among weeds. Not uncommon.

Atylus vulgaris Bate, l. c. 140.

Iphimedia vulgaris Stimps. l. c. p. 53.

At Henley Harbor, in four fathoms; at Square Island, in fifteen fathoms; and at Stag Bay, in fifteen fathoms, on a hard, weedy bottom.

Atylus (Paramphitoe) inermis (Kroyer, *fide* Boeck) [Pl. VIII., fig. 3.]

Cephalothorax produced into a small, flat, acute rostrum, much as in *A. bispinosus.* The first three abdominal segments are produced into three strongly hooked projections, the third of which is much the largest; fourth segment deeply, broadly sinuate. Eyes broadly elliptical, pale. The antennæ are long and slender, subequal in size and length; superior pair three fourths the length of the body, with the peduncle scarcely longer than the antennal ring. Gnathopoda stouter than in *A. bispinosus,* with the propodos rather broad, subtriangular, palm oblique. The posterior pair of abdominal feet extend to the end of the telson which is much longer and slenderer than in the other species, and as in that species, they extend considerably beyond the anterior pair of abdominal legs.

Differs from *A. bispinosus* Bate, in the very hamulate dorsal projection of the first three abdominal rings, in the sinuate fourth ring and the broader gnathopoda, and the much longer abdominal legs and telson. Henley Harbor, ten to twenty fathoms, hard, weedy bottom.

Atylus (Paramphitoe) bispinosus Beck, sp.

Paramphitoe elegans Brug. *fide* Bœck.

Identified by Dr. Boeck, from specimens sent to the Zoölogical Museum at Copenhagen. It occurred rarely with the other species of the genus.

Monoculodes nubilatus nov. sp. [Pl. VIII., fig. 4.]

Female. Cephalic ring produced into an obtuse, tumid rostrum, smaller than in *M. carinatus* Bate, of the British shores; the segments of the thorax and abdomen are not carinated above as in that species, being nearly smooth, while the abdominal segments are slightly sinuated just behind each suture. Eyes small, round, situated just above and opposite the insertion of the superior antennæ; not colored in the adult, but black in the young. Superior antennæ a little longer than the peduncle of the inferior pair; inferior antennæ reaching to the hind edge of the fourth thoracic, including the cephalic, ring; the penultimate and last joint of the peduncle equal in length; flagellum about half the length of the whole antenna. Both pairs of gnathopoda very equal in size, the propodos being long, ovate; anterior pair slenderer than in *M. carinatus*, palm very oblique, with minute hairs; dactylos two thirds the length of the propodos; carpus minute, not prominently produced as in *M. carinatus*, but rather continuous with the propodos. The second pair are much stouter and more ovate than in *M. carinatus*, according in this respect more with that of *M. demissus* Stimps. In form it closely repeats that of the anterior pair; carpus with a long, slender, spine-like prolongation from the palm, forming a thumb closely appressed to the propodos but not extending to the middle. Palm of the propodos on the anterior half fringed with hairs. Dactylos one half as long as the propodos. Anterior pair of thoracic legs subequal; posterior pair of thoracic legs twice as long and much larger than the anterior, coxæ regularly short, pyriform. Abdominal legs large, equal in size, reaching nearly to the tip of the caudal stylets, which are lanceolate, very slender, acute; the first pair being a very little longer than the third. Color pale, mottled with slate. Length, .50 inch.

It differs from *M. demissus* of Grand Menan, in its color, and the very unequal antennæ. From *M. carinatus* of the British Isles it may be readily distinguished by the very equal gnathopoda and non-carinated segments, the slenderer antennæ, and the smaller, round eyes.

Caribou Island, eight fathoms, sand. At Henley Harbor a female, with several young attached to the under side, was dredged in four fathoms, the last of June.

Ampelisca Gaimardi (*fide* Beck.) [Pl VIII., fig. 1, 1 a.]

A slender, thin, much compressed, dorsally wedge-shaped species; head scarcely as much produced as in *A. ingens* Stimps. Eyes four, distinct, small, round and black, situated very near the front margin; rostrum short, rather obtuse. Antennæ remarkably long and slender; superior pair a little more than half the length of the body; basal joint of the peduncle very thick, globose, while the two succeeding joints are very slender; the third joint being very short. The peduncle of the inferior antenna is two thirds as long as the whole superior antenna, being very long and slender, with the basal joint large, cylindrical, the last joint being nearly as long as the penultimate; flagellum long and slender, with long feathery hairs. First pair of gnathopoda small, propodos broad, produced inferiorly; carpus larger than in *A. ingens;* second pair much shorter and stouter than in *A. ingens;* carpus but one fourth longer than the propodos, which is larger and broader than in *A. ingens,* ovate; dactylos long and slender, reaching beyond the middle of the propodos; inferior margin of the joint with fasciculi of long uneven hairs. Legs much as in *A. ingens*, hinder pair of legs shorter and stouter, basos with the expansion reaching to the last joint of the leg, when in *A. ingens* it is short, not reaching beyond the fourth joint from the end; its outer edge is straight; within, full and rounded, convex, edged with thick set hairs; joints of the legs with long feathery hairs. Pleopoda well developed, of nearly even length. Abdomen slightly sinuate, giving a slightly tuberculate outline to the dorsum. Telson long, narrow, much as in *A. ingens*. Length, .50 inch.

This graceful form is readily distinguished from *A. ingens*, apparently its nearest ally, by its remarkably long and slender antennæ, with the globular basal joint of the peduncle of the superior pair; by its compressed cuneate body, the long, broad basos of the hindermost thoracic leg, with its much shorter terminal joints, and short propodos of the second gnathopod.

Not uncommon in Chateau Bay, in thirty fathoms. Cateau Harbor, Long Island, fifteen fathoms, sand. Appearing different from Bate's figures and description of *A. Gaimardi*, I had described it as a new species, but refer to Mr. Beck's identification of my specimen.

Ampelisca pelagica (Stimps.) Pack., Can. Nat. Dec. 1863.

Pseudophthalmus pelagicus Stimps. Gr. Menan. p. 57.

Found at Chateau Bay, in thirty fathoms. At Stag Bay, in ten fathoms, hard bottom. At Caribou Island, in eight fathoms, sand. At Long Island, in fifteen fathoms, sand. Near Strawberry Harbor, in fourteen fathoms, hard bottom.

Ampelisca Eschrichtii Kroyer.

Taken at Caribou Island, in fourteen fathoms. This species was identified by Dr. Stimpson, and also by Mr. Beck.

Haploops tubicola Kroyer.

This is quite a different genus from the foregoing, as specimens received from Dr. Lütken show us. Our specimens agree well with some from Denmark.

Cateau Harbor, Long Island, ten miles above Domino Harbor, in fifteen fathoms, sand, dredged in company with the species of Ampelisca.

Pontoporeia femorata "Kroyer, Nat. Tidsskr. iv. p. 153; Voyage en Scand. pl. 23, fig. 2."

P. femorata Bate, l. c. p. 82. Pl. XIV., fig. 1.

Body robust; antennæ subequal in length; superior pair with the first joint of the flagellum one fourth shorter than the cephalon; whole antenna extending to the third joint of the thorax; appendiculus minute. The first pair of gnathopoda have the propodos longer than the carpus, which is not produced beneath; inferior margin of propodos curved, and nearly parallel with the superior margin. Second pair of gnathopoda with the propodos ovate, twice as long as wide, one third shorter than the carpus, and densely fringed. Basos of the last pair of thoracic legs large, orbicular, hinder edge entire, well rounded; last pair of pleopoda longer than the others. Fourth abdominal segment with a high, erect, stout, very prominent spine, ending in two acute spinules. Length, .40 inch. Kroyer does not figure the spine in the drawing reproduced by Bate; but specimens received from Dr. Lütken agree in all respects with ours. Belles Amours, Straits of Belle Isle, abundant in five to eight fathoms, muddy bottom.

Anonyx ampulla (Phipps), Voyage, 1773.

This species occurred at Dumplin Harbor, Sandwich Bay, in four fathoms. Compared with arctic specimens received from Copenhagen.

Anonyx lagena Kroyer.

Taken at Sloop Harbor in eight fathoms, sand.

Anonyx Hörringii, *fide* Boeck.

A common form, occurring abundantly on the coast of Maine, in Casco Bay, ten fathoms.

Anonyx producta, *fide* BOECK.

These two forms were found together in fifteen fathoms, sand.

Lysianassa appendiculata KROYER.

Forty fathoms, pebbly bottom, three miles from land off Henley Harbor, Straits of Belle Isle.

Alauna Goodsiri BELL in Belcher's Last of the Arctic Voyagers. App. Pl. XXXIV., figs. 2, 3, p. 403.

All of my specimens are of the form, fig. 3, which differs in some characters, such as the less convex form of the carapace, more distinct rugæ anteriorly, and the presence of an acute point on each side of the last leg-bearing segment.

It is an abundant species, being common in from ten to fifty fathoms. Belles Amours, six fathoms. Thomas Bay, fifteen fathoms, mud. Square Island, fifteen to thirty fathoms. Henley Harbor, eight fathoms. Cateau Bay, Long Island, fifteen fathoms, sand.

Mysis oculata FABR.

Abundant along the whole coast. The young go in schools, and the sea-trout consume great numbers of them.

Pandalus annulicornis LEACH.

Abundant on the whole coast, especially in weeds on a clear pebbly bottom twenty fathoms, Henley Harbor. Sloop Harbor, six fathoms. Hopedale, ten fathoms.

Hippolyte aculeata (FABR.) KROYER.

Caribou Island, fourteen fathoms. Square Island, fifteen to thirty fathoms. Domino Harbor, seven fathoms. Straits of Belle Isle, ten fathoms.

Hippolyte polaris (SABINE) KROYER.

It differs from Kroyer's figure in having the upper edge of the rostrum entire, and the terminal spines of the tail are more uniform in size, the three intermediate ones being larger than in Kroyer's figure. Square Island, fifteen to thirty fathoms. Straits of Belle Isle, ten fathoms.

Hippolyte Phippsii KROYER.

One specimen dredged in Domino Harbor, at a depth of seven fathoms.

Hippolyte turgida KROYER.

Found at the Straits of Belle Isle, off Belles Amours, in ten fathoms, on a rocky bottom.

Hippolyte macilenta KROYER.

A rare form, dredged at Square Island, at a depth of fifteen to thirty fathoms.

Hippolyte Sowerbyi LEACH.

This species was obtained with the preceding; it is not common.

Hippolyte Gaimardi M. Edwards.

Common on the whole coast. Caribou Island, fifteen fathoms. Square Island, thirty fathoms. Henley Harbor and Sloop Harbor, eight fathoms. Hopedale, ten fathoms.

Hippolyte Fabricii Kroyer.

Found in Domino Harbor, at a depth of seven fathoms; it is not common.

Argis lar Owen.

This species was dredged at Square Island, in thirty fathoms; it is not common.

Sabinea septemcarinata Sabine.

This species occurred in Thomas Bay, at a depth of fifteen fathoms.

Crangon boreas (Phipps.)

Caribou Island, eight fathoms, and Straits of Belle Isle, ten fathoms. Square Island, thirty fathoms, and Henley Harbor, ten fathoms; whole coast. One specimen taken at Henley Harbor in four fathoms, had a Pontobdella an inch long attached to the under surface.

Crangon vulgaris Fabr.

This species was only noticed on the mud flats at Caribou Island, where it was abundant.

Homarus americanus M. Edw.

Found at Henley Harbor; rare. This seems to be the northern limits of the Lobster.

Eupagurus pubescens Stimps.

Abundant on the whole coast from low-water mark to fifty fathoms. Straits of Belle Isle, fifty fathoms. Hopedale, ten fathoms.

Eupagurus Kroyeri Stimps.

This species was found with the preceding ones, but not in such abundance.

Hyas coarctata Leach.

Dredged at a depth of thirty fathoms, in Henley Harbor. It is not very common.

Hyas aranea (Linn.)

Abundant, and often of large size, found along the whole coast from five to fifty fathoms.

Chionœcetes opilio (Fabr.)

Not uncommon in the Straits of Belle Isle, in ten to fifty fathoms; at Chateau Bay, in thirty to fifty fathoms.

Cancer borealis Stimps.

Not uncommon at Caribou Island, Straits of Belle Isle, but it did not occur to us northward. I was informed that it was found in Hamilton Inlet, where the temperature of the water must be higher than on the coast.

Explanation of Plate VII.

Fig. 1. — Astarte striata Leach.
Fig. 2. — Macoma fusca Stimpson *var.*
Fig. 3. — Buccinum undulatum Möller *var.* (young.)
Fig. 4. — " " " (adult.)
Fig. 5. — " grœnlandicum Hancock, fossil, Labrador. 5*a*. Fossil, Chateau Bay. 5*b*. Recent. 5*c*. Operculum of recent specimen.
Fig. 6. — Buccinum tenue (scalariforme) Gray.
Fig. 7. — " cretaceum Reeve.
Fig. 8. — Fusus labradorensis Packard.
Fig. 9. — Buccinum cyaneum Brug. fossil from Montreal.
Fig. 10. — " " " recent from Newfoundland.
Fig. 11. — Bela americana Packard *var.*
Fig. 12. — " robusta Packard.
Fig. 13. — Fusus syrtensis Packard.
Fig. 14. — Cardium Hayesii Stimpson.
Fig. 15. 15*a*. — Margarita campanulata Morse.
Fig. 16. — Flustra digitata Packard.
Fig. 17. — Eschara papposa Packard. 17*a*. Avicularium when gaping. 17*b*. The same, seen laterally.
Fig. 18, 18*a*. 18*b*. — Teeth of the Bison, from the Leda Clays of Gardiner, Maine.

Explanation of Plate VIII.

Fig. 1. — Ampelisca Gaimardi. 1*a*. Anterior foot.
Fig. 2. — Calliope læviuscula Kroyer, anterior foot. 2*a*. The same with dactyls open.
Fig. 3. — Atylus inermis (Kroyer) abdomen. 3*a*. Anterior foot. 3*b*. The same with the claws closed.
Fig. 4. — Monoculodes nubilatus Packard.
Fig. 5. — Bopyrus mysidum ♀ Packard, underside.
Fig. 6. — Idotæa marmorata Packard.
Fig. 7. — Pontopordia femorata Kroyer, second gnathapod.
Fig. 8. — Phascolosoma hamatula Packard.
Fig. 9. — Pontobdella? livida Packard.
Fig. 10. — Syrinx sp.
Fig. 11. — Cerebratulus cylindricus Packard, head.
Fig. 12. — Geological Map of the Coast of Labrador south of Hopedale.

Published May, 1867.

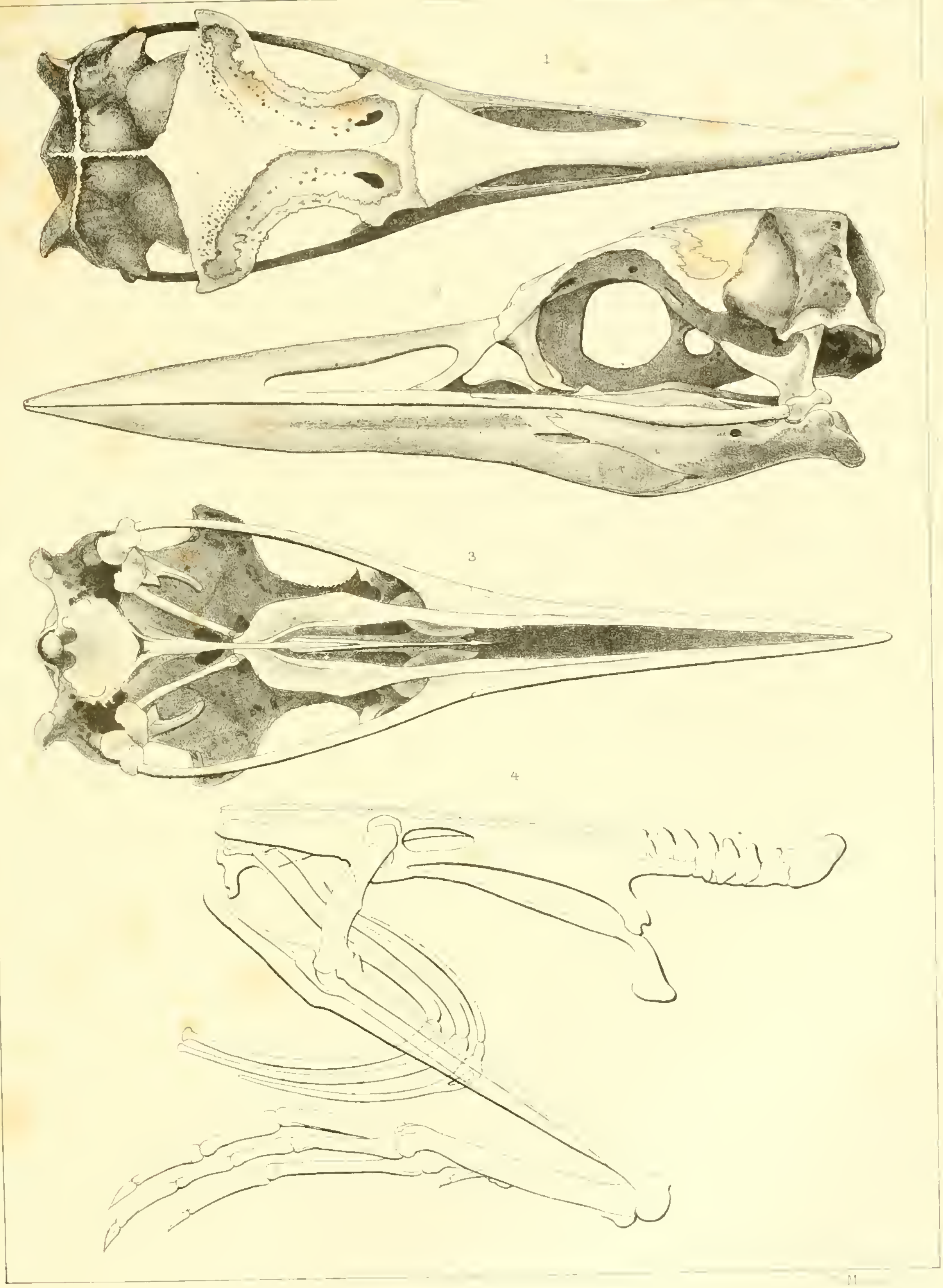
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Fig. 1

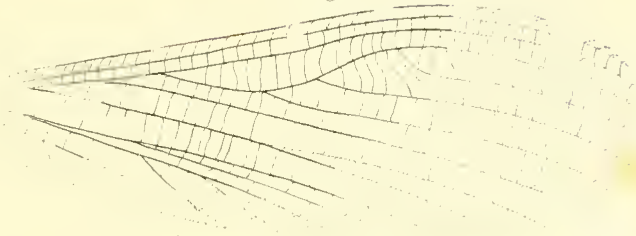


Fig. 2

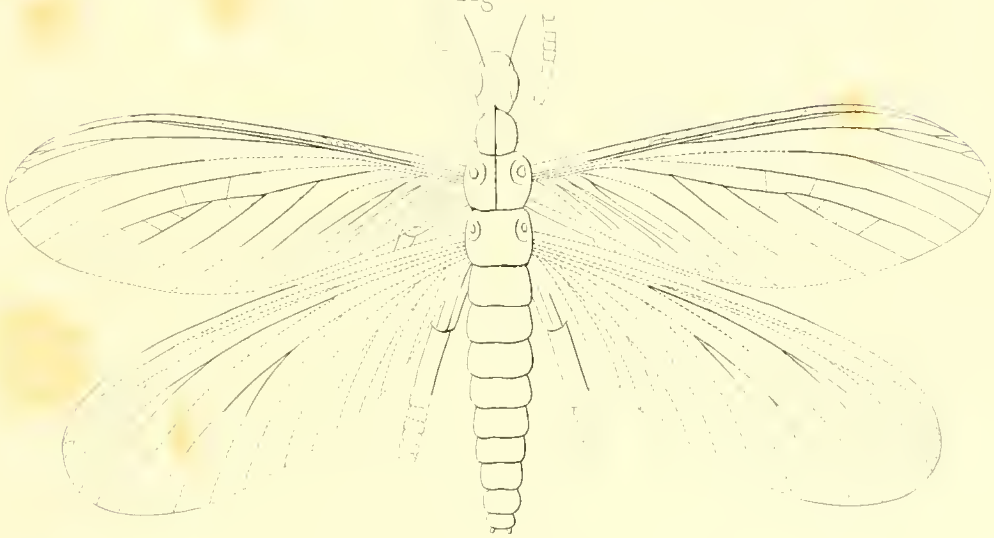


Fig. 3

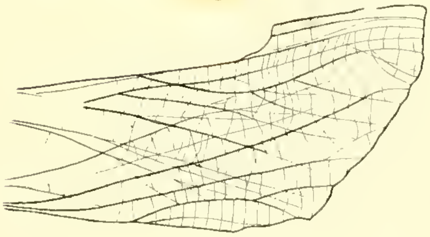
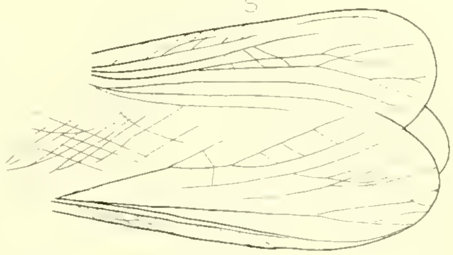
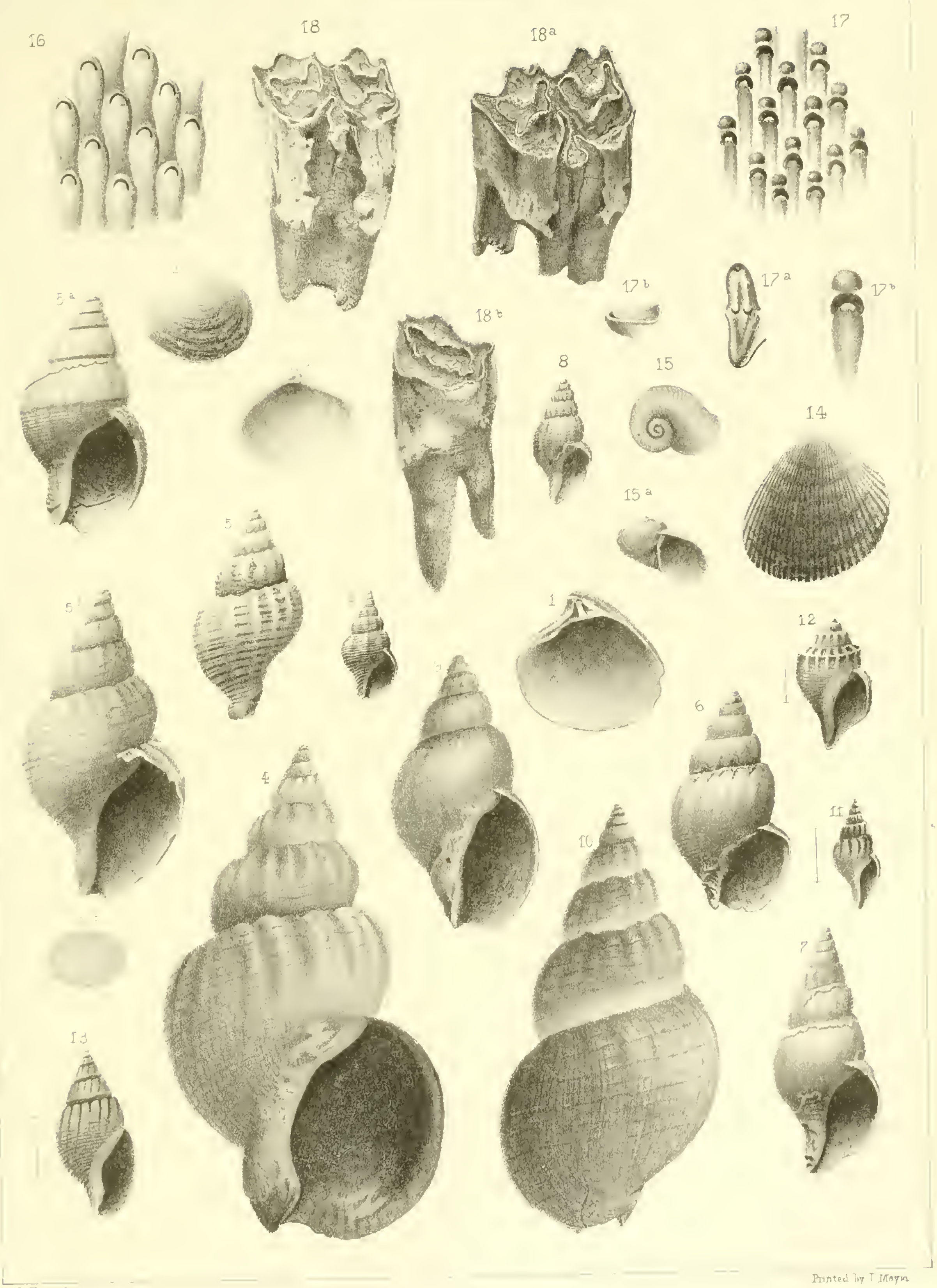


Fig. 4



L. Trouvelot on stone

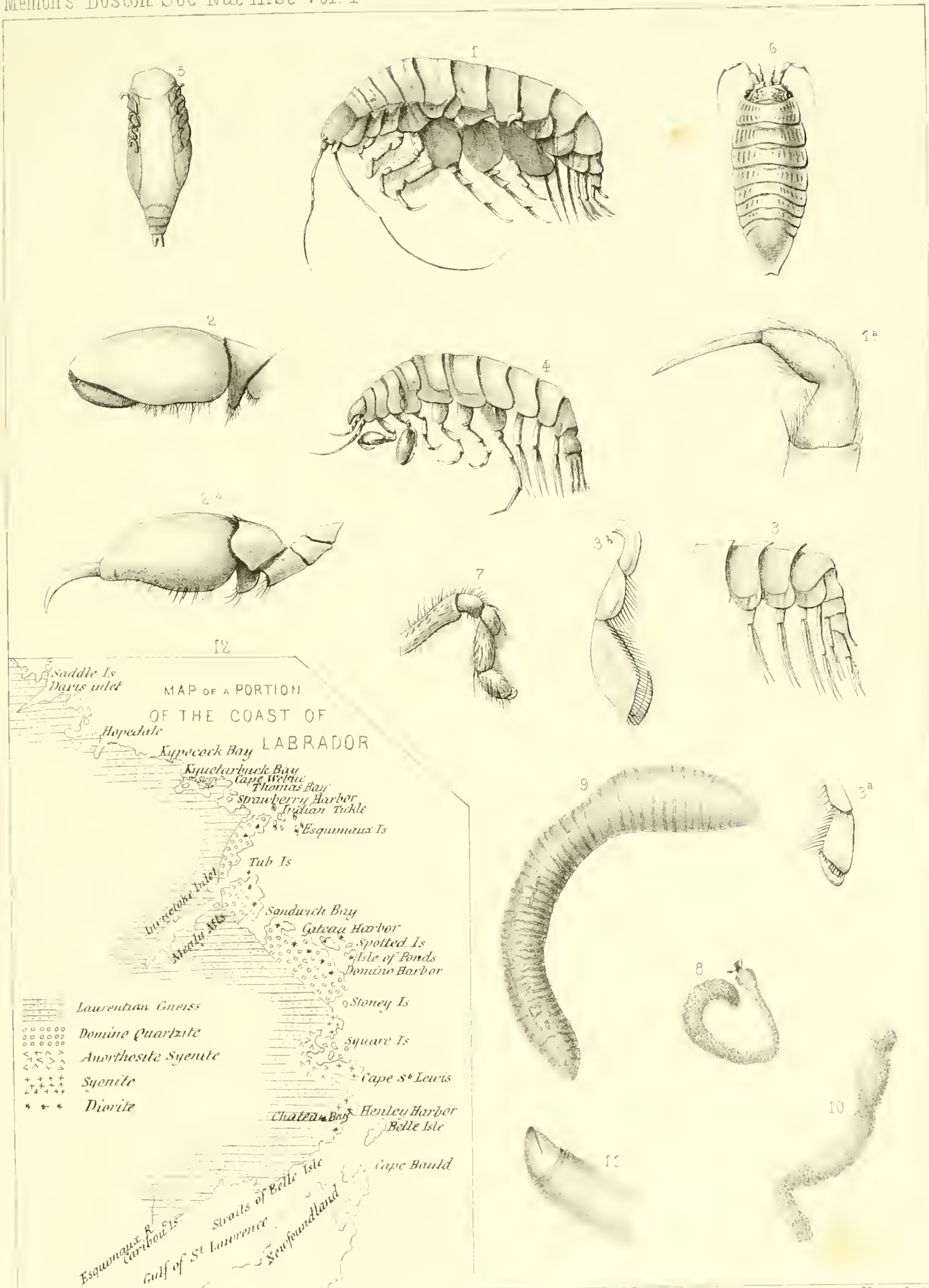
Scudder on the Wings of fossil Neuroptera



L. Trouvelot on stone

Printed by J. Mayer

Packard on the Glacial Phenomena and marine Invertebrates of Labrador.



Morse from nat. L. T. Mayers Lith.

Packard on the Glacial Phenomena and marine Invertebrates of Labrador

MEMOIRS

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BEING A NEW SERIES

OF THE

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MEMOIRS

READ BEFORE THE BOSTON SOCIETY OF NATURAL HISTORY.

VOLUME I. PART III.

IX. *On the* Spongiæ Ciliatæ *as* Infusoria Flagellata; *or, Observations on the Structure, Animality, and Relationship of* Leucosolenia botryoides, *Bowerbank.*[1] *By* H. JAMES-CLARK, A. B., B. S. Professor of Natural History in the Agricultural College of Pennsylvania.

Read June 20, 1866.

I HAVE been engaged, like others, for some time past, endeavoring to clear up the doubt which prevails in the scientific community in regard to the nature of the Sponge. The question has been, is it an animal or is it a plant? Bowerbank, the highest classificatory authority upon this subject, for a long term of years held that it was an animal, but his *bases* for this theory were such that they did not appear to offer a satisfactory means of finally deciding the dispute. The latter remark applies with equal force to the investigations of Lieberkühn. Of later years Carter has made some special investigations in reference to this subject, and in fact he has been the first one to present any thing like decisive proofs of the animality of the Sponge. A few words quoted from his paper, which he published in the "Annals and Magazine of Natural History" for April, 1857, Vol. xx. p. 30, will suffice to show to what extent he has carried his observations. Speaking of the "monociliated sponge-cells of the ampullaceous sac," — which he says was set free by the disintegration of the whole mass of the sponge, — he remarks that "particles . . . . . were thrown [by the flagellum] almost point-blank on its surface and rapidly passed into the interior." Strangely enough, though, as it seems to me now, he does not look upon the intussusception of the particles as a genuine process of swallowing, like that which obtains among the ciliated infusoria, but describes it, in several places, when speaking of the various kinds of sponge-cells, as an enveloping of the food after the manner of *Amœba.* It is plain, therefore, that he does not believe that the "sponge-cells" are endowed with a *mouth*, and, moreover, if I am not mistaken, he attributes to any part of the "cell" the faculty of engulfing food. This interpretation, therefore, would exclude the Sponge from the list of *Flagellata*, notwithstanding the presence of the *flagellum.* That, however, does not weaken the proof as to the animality of this organism, but merely leaves it — as Mr. Carter believes it to be — in the most intimate alliance with the naked *Rhizopoda*; and, as if to confirm this conclusion, the same authority adds, "These monociliated sponge-cells present the contracting vesicle[2] in great activity, but also in variable plurality." I believe, however, that the "variable plu-

[1] A sketch of the contents of this memoir has already been published in the Proceedings of this Society for June 20, 1866; and in the *American Journal of Science* for November, 1866.

[2] Already noticed by him in 1847, in the *Trans. Bombay Med. and Phys. Soc.*; abstract in *Annals Mag. Nat. Hist.*, 1848.

rality" of the contracting vesicles does not alone belong to the *Rhizopoda*, but, as I shall show hereafter,[1] that it is also to be observed among the true *Flagellata;* and I would remark, moreover, that when we consider the close relationship — which I hope to prove in this paper — of the Sponge to the other flagellate, monad-like infusoria, which undoubtedly have a definite oral aperture, we must, if on no other grounds, conclude that it also possesses a true mouth.

Still there would appear to be some who doubt whether, after all, the Sponges are really animals instead of plants, and, moreover, seem to insist that they are neither the one nor the other, but form, with other infusorians — such as *Volvox, Gonium, Pandorina, Euglena*, and other conferva-like bodies — a group by themselves, standing intermediate to, and partaking of the nature of, both animals and plants. This is the group which has been called *Phytozoa*, i. e. plant-animals.

In the midst of this halting decision, I have been, for some years past, working upon a class of infusoria, the knowledge of whose structure fully prepared me not only to recognize the animal nature of the Sponge, but also enabled me to determine to what group of infusoria it belongs. Such a decision, therefore, does not leave any trace of doubt in my mind as to the strictly animal nature of the Sponges. The whole question in dispute hinges upon the determination as to the animal or vegetable nature of the Monad-like, or so-called flagellate infusoria. And here again I would say that it has fallen to my lot to decide, for the first time, that one of the smallest known of the infusoria, the Monad, (*Monas termo*, Ehr ?) is an animal. If, now, we can prove this point, the way is perfectly clear through the intermediate forms which lie between the Monad and the Sponge.

Commencing, then, with what I believe to be the *Monas termo* of Ehrenberg, I shall proceed to describe in detail a series of forms — several of which are new, both generically and specifically — which stand in the closest relationship among the lowest embodiments of infusorial life, embracing among them, as I hope to show, the true ciliated sponges, and which, notwithstanding, lead in unobstructed, although varied courses,[2] to the more elevated kinds of *Protozoa*, the true *Infusoria Ciliata.*

§ 1. Monas termo, Ehr ?

(Plate IX., figs. 1, 2, 3, 4.)

Upon a slight acquaintance with this infusorian, one would be strongly inclined to identify it with the younger stages of *Anthophysa Mülleri*. Bory. (fig. 49); but a more searching investigation reveals such a number of characters in each which are not to be found in the other that one need not have any hesitation whatever in setting them down as totally diverse organisms. In fact, *Monas* belongs to the uniciliate *Flagellata*, whilst the other genus just mentioned is a biciliate, heteronematous form.

Monas lives in two diverse conditions, of which one is a fixed state (fig. 3), and the other a free and motile stage (figs. 1, 2, 4). During its sedentary life it may be found in great abundance on the old stems of *Myriophyllum, Potamogeton, Ceratophyllum*, and other aquatic, phenogamous plants which inhabit quiet waters, and are more or less thickly covered by a floccose overgrowth of various minute *Confervæ, Diatomaceæ*, etc. In its free state it swims with either a sort of hitching, wriggling motion, or, gliding along smoothly, revolves at an

[1] *Salpingœca marinus*, nov. sp. § 8, and *S. amphoridium*, nov. sp. § 9.

[2] See the preliminary remarks upon *Anthophysa*, § 11.

inconstant but never rapid rate upon its longer axis, of which the flagellum (fig. 2, *fl*), which always precedes it, may be said to be a prolongation. This is the condition in which it is most frequently to be found after it has been kept a few days in an aquarium. It then gathers in swarms about decomposing matter, and thus affords frequent opportunity of seeing its mode of collecting and swallowing its food.

The *form* of the body in a fixed state (fig. 3) may be compared to a flattened heart, of which one summit is prolonged into a broad, conical, transparent beak (*lp*), and at the opposite end the apex is attached to a slender, flexible pedicel (*pd*), which frequently is equal in length to four or five times the antero-posterior diameter of the body. In a free condition (fig. 2) the posterior end is rounded and about as broad as the front, but still it presents the same lateral flattening as the fixed form. The prevailing color is a faint olive or yellowish green.

The *flagellum* (*fl*) is the only cilium-like organ which this creature possesses. It is attached to the front, close to the proximal side of the conical beak (*lp*), and consequently lies in the axial line of the body. In a quiet state, which it most frequently assumes during the fixed condition, it appears like an arcuate bristle, and extends from near its base to its apex in one uniform, slightly but distinctly curved line, and terminates without any very sensible diminution in thickness. The plane of its curve is in direct extension of the plane of the greater diameter of the body, and at the same time passes through the conical beak. During natation the flagellum takes precedence and vibrates with an undulating, whirling motion, which is most especially observable at its tip, and produces by this mode of propulsion the peculiar rolling of the body, which at times lends so much grace to its movements as it glides from place to place. During the fixed state of the body the chief design of the movements of the flagellum is the prehension of food; and this is accomplished by a peculiar, abrupt deflection of the end of this organ toward the *front*, by means of which particles of various kinds are made to impinge upon the region immediately at the proximal side of the base of the broad, conical beak; — a point at which, as will be seen presently, the mouth is situated.

The *mouth* (figs. 3, 4, *m*) lies between the base of the flagellum (*fl*) and the beak, or *lip* (*lp*), as I shall hereafter designate it, from its obvious office, presently to be described. A plane, therefore, drawn through the lip and the base of the flagellum, would also strike the mouth, and moreover form a continuation of that of the greater diameter of the body. This aperture is not visible during its closed state, but its presence has been often and unmistakably determined by seeing the masses of food enter invariably at the point designated above. As already stated, particles are thrown with a sudden jerk, precisely as is done by *Anthophysa Mülleri*, Bory. (figs. 50, 51), and apparently with great precision, directly against the mouth (fig. 4, *m*). If acceptable for food, the flagellum presses its base down upon the morsel, and at the same time the lip is thrown back (fig. 4, *lp*) so as to disclose the mouth, and then bent over the particle as it sinks into the latter. When the lip has obtained a fair hold upon the food, the flagellum withdraws from its incumbent position and returns to its former rigid, watchful condition (fig. 4, *fl*). The process of deglutition is then carried on by the help of the lip alone, which expands laterally until it completely overlies the particle. All this is done quite rapidly, in a few seconds, and then the food glides quickly into the depths of the body, and is enveloped in a digestive vacuole (*d*), whilst the lip assumes its usual conical shape and proportions.

The *contractile vesicle* (figs. 2, 3, 4, *cv*) is a much larger and far more active organ than that of *Anthophysa* (figs. 47, 48, *cv*). If we view the body from its narrower aspect (fig. 2), when it stands so that the lip (*lp*) is nearest the eye, the contractile vesicle (*cv*) appears in profile, on the left broad side, and so close to the surface that it seems to project beyond the general outline of the body. It lies in the anterior third of the broad side just mentioned, and close to the transverse plane which separates that part which contains it from the one upon which the lip is placed. From whichever direction, therefore, one views this organ, it will be seen to stand in an asymmetrical relation to the rest; and as it is preëminently a dominant feature, it may serve, perhaps better than any other, as a starting-point in determining the obliquity of the type of this infusorian, and its perfect consonance in this respect with that of the more obviously spiral forms, such, for instance, as are exemplified by *Dysteria* (figs. 77, 78) and *Pleuronema* (figs. 75, 76). It is so large and conspicuous that its globular form may be readily seen, even through the greatest diameter of the body; and contracts so vigorously and abruptly, at the rate of *six times a minute*, that there seems to be a quite sensible shock over that side of the body in which it is imbedded.

The *reproductive organ* may possibly be represented by the very conspicuous, bright, highly refracting, colorless, oil-like globule (*n*), which is inclosed in a clear vesicle, and appears to be so constantly present in the depths of the posterior third of the body. Its position seems to be invariably on that side of the transverse axial plane which is opposite to that in which the contractile vesicle (*cv*) lies. Nothing further of a positive nature can be said in regard to this body, but we may conjecture that, inasmuch as it cannot well be assigned to any other office, — not even to that of an eye-spot, — it is in all probability an organ of reproduction.

In regard to the *stem* (fig. 3, *pd*), it may be added that although it appears to be of the simplest nature, a mere gossamer thread as it were, it is none the less positive, as a support, than that of *Anthophysa* (figs. 47, 48, 49, *pd*), and must indeed possess a similar self-reliant power in order to keep the body in the same relative position in regard to the object to which it is attached, or to sustain it in an upright attitude at a time when the flagellum is quiet, and there is consequently no other means of preventing the animal from sinking down upon the nearest fixed point.

§ 2. Monas neglecta, nov. sp.

(Plate IX., figs. 5, 5ª, 5ᵇ, 6.)

To a casual observer this species would appear to be one of the varieties of *Monas termo* of § 1, and I must confess that under an amplification of only five hundred diameters the mistake would be easily made, unless one had become perfectly familiar with the two by prolonged study with a much higher magnifying power. There is, though, a physiological difference which can be observed when all others could scarcely be noted, which is this: the rate of the systole of the contractile vesicle (*cv*) of this species is double that of *Monas termo*. Like the latter it enjoys two diverse conditions of life, namely, a fixed (figs. 5, 5ª, 6) and a free (fig. 5ᵇ) state; frequents the same habitat; progresses with the same means and mode of locomotion, and obtains its food by similar prehensile organs, and swallows it in the same manner.

The *form* of the body is that of an oval, but terminates anteriorly in an obliquely truncate front; or rather one side of the front projects in the form of a low, rounded prominence, which constitutes the *lip* (*lp*). The posterior end is either broadly rounded or very bluntly pointed where the pedicel (*pd*) is attached. The color is either grayish or there is none at all.

The *flagellum* (*fl*) has more of a sigmoid flexure than that of *Monas termo* (figs. 1–4), and about as much as that of *Anthophysa Mülleri*, Bory (figs. 47, 48, *fl*). It arises from the axial point of the front, and extends to about three times the length of the body. The plane of its curve bears the same relation to the mouth and lip as that of *Monas termo*, and it is used in the same manner as a prehensile organ to assist the lip (fig. 6, *lp*), when taking food, and for a propelling apparatus (fig. 5^b, *fl*) as the body whirls along after it during natation.

The *mouth* (fig. 6, *m*) lies in the same relative position as that of *Monas termo*, and receives its food in precisely the same manner, and, by the assistance of the lip (*lp*), with the same degree of rapidity passes it into the body.

The *contractile vesicle* (*cv*) lies on the same side of the plane of the arcuate flagellum (*fl*) as that of *Monas termo*, and at about the same distance from the front, but in an opposite region, and directly in the antero-posterior line with the lip. It is also a more vigorous and larger organ than that of the other *Monas*, and, bulging out (fig. 5^a, *cv*) the body even more strongly during expansion, its systole takes place at double the rate, that is, *twelve times a minute*, and very abruptly.

The *pedicel* (*pd*) sometimes attains to four or five times the length of the body, but most frequently it is not more than half as long as that. It is thin and delicate, but appears to possess considerable rigidity, either in a fully extended state, or when — as appears to be the case sometimes — it is contracted into more or less abrupt curves (fig. 6, *pd*). Its apex (fig. 5^a, pd^1) is attached to the posterior end of the body at a point which is coincident with the longitudinal axis.

§ 3. Bicosœca, nov. gen.[1] (B. gracilipes, nov. sp.)
(Plate IX., figs. 34, 35.)

This genus might be compared to a *Monas* seated in a calyx, and upon a highly muscular, contractile stem.

Bicosœca gracilipes is a marine form, and has thus far been found, although in considerable numbers, only upon *Sertularia cupressina* Linn. It is an excessively minute creature; as may be readily judged by the reader upon referring to the magnifying powers which are laid down in the description of the figures. When first met with it appeared, upon a casual observation, and under a magnifying power of only five hundred diameters, to be an elongate, naked *Monas*, which was kept in a firm position by some invisible power. It soon, however, attracted particular attention to itself by its peculiar, spasmodic, and often repeated retrocession. Upon putting on a power of eight hundred diameters the whole organization was brought out with sufficient clearness to satisfy one upon every point. For the purposes of illustration, however, it was thought best to increase the magnifying power to a still greater extent, and we have, therefore, drawn one figure (fig. 34) to represent this infusorian as it appears when seen under an amplification of about fifteen hundred diameters.

This animal has never been found in a free state, nor in any other than that which is represented in these two figures, (figs. 34, 35). It has an elongate oval body which is enclosed in a deep, vasiform, pedicellated calyx (*c*), to whose bottom it is attached by a slen

[1] βίκος, a vase; οἰκέω, to inhabit.

der, colorless, contractile ligament (*r*). It usually rests about half way between the top and bottom of the calyx, but is frequently jerked to the bottom (fig. 35) of the vase (*c*) by means of the ligament just mentioned. The anterior end is truncate, and prolonged into two prehensile organs, one of which is a *flagellum* (*fl*) and the other a *lip* (*lp*) similar in position and function to that of the *Monas* described in the previous section. The generally prevailing fuscous tint is interrupted by a transparent, colorless streak (r^1) which extends from the laterally posited base of the flagellum (*fl*) to the posterior end of the body, where it seems to be prolonged into the contractile ligament (*r*). It is not a band, however, but a sharply defined furrow, of considerable depth. At the anterior end it is sunk so deeply that it borders closely upon the base of the flagellum, and from that point it gradually shallows until it nearly disappears at the point of junction of the body with the contractile ligament.

We are thus reminded of those heteronematous *flagellata*, like *Anisonema* (figs. 65–69), whose bodies are so conspicuously sulcated in a longitudinal direction; and the apparent continuation of the retractor ligament (fig. 34, *r*) with this furrow (r^1) heightens the impression, by its resemblance to the highly muscular, trailing lash (figs. 65–69, fl^2) of that genus. One could hardly be accused of unduly straining a point in homology if he were to consider the furrow (fig. 34, r^1) in question as merely a greatly prolonged ostial notch, and the retractor (*r*) as a trailing lash, which originated at the greatest possible distance from the other, its proboscidal companion (*fl*).

The *lip* (*lp*) is a more prominent organ than that of *Monas*. It has a conical shape, and is about twice as long as its greatest breadth. It is so hyaline as to readily escape notice until it is fully recognized. It is situated at the edge of the truncate front opposite to that from which the flagellum arises, and therefore leaves a considerable space between the latter and itself. Within this broad space the simple mouth (*m*) is situated.

The *flagellum* (*fl*) is the most active of the prehensile organs, and the only vibratory, filamentous body which this animalcule possesses. In length it is about three times that of the body, or a little more, and projects far beyond the rim of the vase (*c*). It is a curious fact that while in *Monas* and *Anthophysa* the lip and flagellum lie closely together, they stand far apart in *Bicosœca*. The flagellum is not an undulatory, vibrating organ, in the common sense of the term, but usually supports itself in a rigid condition, except at the tip, which is kept in nearly constant motion, incurvating with frequent jerks, and tossing floating particles toward the mouth. Its distal two thirds is quite strongly curved, but not so much as to be absolutely falcate; and at its basal third it is moderately arcuated in the opposite direction, so that the whole flagellum has a slightly sigmoid flexure. The plane of this curve is such as to strike the mouth and lip when carried out in that direction. The diameter of this organ is about equal from tip to base, excepting a slight thickening at the latter point. The only times that the flagellum abandons its rigid deportment is either when it is assisting the lip to seize the food, or during the spasmodic retrocession of the body. In the latter case it is abruptly retracted and coiled (fig. 35, *fl*) transversely within the calyx (*c*) close down to the truncate front of the body. When the latter slowly pushes forward from the bottom of its dormitory, the flagellum as deliberately uncoils, and at first vibrates with a rapid wriggle, but finally assumes its former sigmoid curve and rigid deportment.

The *mouth* (*m*), as has already been mentioned incidentally, lies in the middle of the truncate front, and consequently faces toward the aperture of the calyx (*c*). Food is brought to it by means of the flagellum (*fl*); and the latter and the lip (*lp*) force it into the oral aperture exactly in the same way as has been described in regard to *Monas*.

The *contractile vesicle* (*cv*) is a single globular organ, which lies on the corresponding side of the body with that of *Monas*, and just in front of the middle. In full diastole its diameter equals one third of that of the body. Both the systole and diastole are very slow.

The *calyx* (*c*) is about twice as long as the body which it encloses, and between four and five times its own average diameter. It has the form of a very deep, slender urn, with a rounded bottom, slightly contracted waist, and a very delicate, scarcely reverted, truncate rim. It is so hyaline and faint that it almost defies any magnifying power below that of eight hundred diameters. The pedicel (*pd*) which supports it is at least twice as long, of uniform diameter throughout, and very slender, in fact not much thicker than the flagellum. It is attached (pd^1) to the bottom of the calyx exactly opposite to the point from which the contractile ligament (*r*) arises, but, unlike the latter, it appears to be totally incapable of contraction.

§ 4. Bicosœca lacustris, nov. sp.

(Plate IX., figs. 33, 33^a, 33^b, 33^c.)

This species lives in quiet streams and lakes, attached to filamentous *Algæ*, and is quite common, especially on old specimens of *Zygnema*. It is tinged throughout with a yellowish color, which seems to add a good deal to the difficulty of distinguishing its various parts. When protruded (fig. 33) it occupies the anterior half of the calyx (*c*) and projects a little beyond its edge, and consequently its retractor ligament (*r*) stretches over the whole posterior half of the dormitory. The shape is rather elliptical than elongate-oval, but it varies more or less between these two forms, and seems to have the latter shape in the largest individuals. Posteriorly the body is rounded, but its broadest region is about the middle, and from thence it tapers considerably to a truncate front, and ends on one side in a laterally projecting *flagellum* (*fl*), and on the opposite side in a long incurved *lip* (*lp*).

The longitudinal furrow (r^1) which is so conspicuous in *B. gracilipes* is much narrower in this species and not so deep, yet it holds exactly the same relations to the base of the flagellum (*fl*), and the contractile ligament (*r*). After a number of observations upon the frequent and sudden retraction of the body to the bottom of its calyx, during which in every instance that side along which the furrow (fig. 33^c, r^1) runs was contracted much more than the opposite one, I feel quite confident that this sulcus is the seat of a highly contractile band, and moreover that it is continuous with the posterior retractor ligament (*r*). The latter is very slender and thread-like, and is attached to the posterior end of the body on one side (see fig. 33^a, *r*) of its axial line, and has very much the appearance of being a free continuation of a ligament in the furrow just mentioned. The *lip* is nearly twice as long in proportion to the breadth of the front as that of *B. gracilipes*, and has an incurved, digitate form (figs. 33, 33^a, *lp*).

The *flagellum* (*fl*) is the most remarkable and distinguishing feature of this species, when contrasted with *B. gracilipes*, on account of the wide angle at which it diverges from the longitudinal axis of the body; for whilst in the latter it deviates but little from parallelism with the axial line, in the former it arises at an angle of from forty to forty-five degrees (fig. 33^a, *fl*) with the same line. At its base it curves away from the lip, but for the remaining four fifths it bends with a long arch in the opposite direction, but not so much as to bring its tip in a line with the body. It is therefore altogether eccentric, but yet its curve lies in the same plane relatively to the mouth and lip as that of its marine congener. Its length is about two and a half times greater than that of the body, and it scarcely, if at all, tapers from one end to the other. It usually is held in a rigid attitude, except at the tip, which is always kept in a rapidly gyrating state, accompanied frequently by spasmodic incurvatures, when floating particles are thrown by it toward the mouth (*m*). Its flexibility is exhibited during the frequent spasmodic retrocessions of the body (fig. 33ᶜ) in the same way as in the other species, and the like remark applies to its action when assisting the lip to force the food into the mouth.

The *mouth* (*m*) opens in a slight hollow which lies between the base of the flagellum on one side and the lip on the other, and therefore is concentric with the longitudinal axis of the body. It very readily takes in quite large particles (fig. 33, *m*) of food, with the aid of the incurvating lip (*lp*) and the flagellum (*fl*), and immediately encloses them in a digestive vacuole, or, more properly speaking, a hyaline envelope, within which they revolve for a while with considerable rapidity. The *anus* (fig. 33, *a*) lies in the same hollow as the mouth, but further up on the base of the lip. That it is distinct from the mouth was frequently demonstrated by the collection of large globular masses in the base of the lip, and sometimes further up, and their subsequent exit thereabouts.

The *two contractile vesicles* (*cv*, *cv*,) form another very strong mark of distinction, since they are not only double the number of that of *B. gracilipes*, but are also situated at the extreme posterior end of the body. They are quite conspicuous, and appear to lie right and left of the plane which passes through the lip, flagellum, and furrow. The systole of each alternates with the other, and occurs from five to six times in a minute, but with nothing remarkable in its action, unless it be that it operates more moderately than in *Monas*.

The *calyx* (*c*) has, in its fully developed condition, about the same shape and proportions as that of the marine form (figs. 34, 35), but like the body, it is much larger. In its younger stages (figs. 33ᵃ, 33ᵇ, 33ᶜ *c*, c^1,) its aperture (c^1) almost closes when the body is retracted (fig. 33ᶜ), and during the protrusion of the latter its rim (fig. 33ᵃ, c^1) embraces it very closely; so that on the whole the calicle has an elongate ovate shape, with a narrowed, truncate, smooth margin. During the undeveloped stages of the calyx, the *pedicel* (*pd*) is less than half its length, and from that it varies down to little (figs. 33ᵃ, 33ᶜ, *pd*) or nothing; but when the former is full grown (fig. 33, *c*), the latter (*pd*) is at least half as long as it. It is more slender than that of *B. gracilipes*, and like the latter is attached to the base of the calyx opposite the insertion of the retractor ligament (*r*).

§ 5. Codonœca, nov. gen.[1] (C. costata, nov. sp.)

(Plate IX., fig. 36.)

Of all the calyculate *Flagellata*, the species before us is perhaps by far the most beautiful, both in physiognomy and proportions. It is a marine form, and was found with *Bicosœca gracilipes*. Generically it differs from *Bicosœca* (§§ 3 and 4) in having neither a basal, retractor muscle, nor lip, nor lateral longitudinal furrow, and by the attachment of its single flagellum (*fl*) to the central point of the front. From *Salpingœca* (§§ 7, 8, and 9) it differs principally in not possessing a projecting collar or rim about the anterior end, but, as in

[1] κώδων, a bell; οἰκέω, to inhabit.

that genus, the body is not attached to the calyx by any visible means. It cannot be a Dinobryon, since that, as Claparède has already shown, has but a single contractile vesicle, and moreover it is situated near the anterior end of the body, and just behind a red eye-spot. Dinobryon has a slightly notched, asymmetrical front; in fact, it is a calyculated *Euglenian.* The general tint of the body of *Codonœca costata* is a dingy yellow, whilst the calyx (c) is colorless, and excessively transparent. The shape of the body is oblong, rounded posteriorly, and slightly pointed in front, where the flagellum (*fl*) is attached. Its posterior half nearly fills the basal third (c^2) of the calyx.

The *flagellum* (*fl*) has not that rigid carriage which is so characteristic of that of *Bicosœca* (§§ 3 and 4) and *Anthophysa* (§ 11), but is a truly vibratile organ. It is kept in an almost constant state of rapid agitation, and projects at the same time far beyond the rim (c^1) of the calyx. It is by no means easy to detect, even with a power of eight hundred diameters, not only because it is seldom at rest, but on account of its excessive delicacy; yet when it does stop its vibrations, its character and proportions can be unequivocally demonstrated under the proper circumstances of illumination and adjustment. It is about twice as long as the body, and has a decided, although not rapid taper at its distal termination.

The *mouth* remains yet to be discovered. There can be no doubt, however, that it is an aperture of no very small extent, or at least that it is capable of considerable distension, inasmuch as we find quite large angular particles within the body. That it is terminal rather than lateral, is probable from the similar position of this organ in the not very distantly allied genus *Codosiga* (§ 6).

The two *contractile vesicles* (*cv*, *cv*) are situated midway between the front and hind ends of the body, and at two nearly opposite points. They are of moderate size, yet not so large as those of *Codosiga* (§ 6), which they resemble, but exhibit a much feebler action than the latter.

The *calyx* (c, c^1 c^2), or carapace so called, has an ovate-campanulate outline, but is divided, by a constriction, into two regions. One of these, the basal (c^2) or posterior third, is about one half as wide as the remaining two thirds (c), and possesses an ovate-obconical form, which tapers abruptly into the pedicel (*pd*). The anterior two thirds (c) arises from the sharp constriction with a strong swell, or bulging, and then, narrowing a little, terminates with a truncate aperture (c^1); so that on the whole this portion may be compared, in shape and proportions, to a claret-glass. This region is peculiar moreover in being longitudinally banded or sulcated by about twenty furrows, which terminate at the rim in as many notches, that alternate with a like number of distinct scallops. Of these two regions the basal one is quite distinct, although perfectly hyaline; but the banded part is much fainter, and requires a careful adjustment of the light in order to bring it out clearly. The *pedicel* (*pd*) is moderately slender, colorless, at least as long as the calyx, and of a uniform thickness from base to top.

§ 6. Codosiga, nov. gen.[1] (C. pulcherrimus, nov. sp.)

(Plate IX., figs. 7–27.)

This infusorian is as eminently a compound flagellifer as *Anthophysa* (§ 11); and although not a heteronematous form, like the latter, it bears a very striking general resemblance to

[1] κώδων, a bell; σίγαω, to be silent.

it; as one may see by comparing figures 8 and 47 with each other. It also frequents the same habitat as *Anthophysa*, where it is quite abundant, and readily recognized, when one has become familiar with it, even under as low a magnifying power as two hundred diameters. The greater number of individuals are found attached singly (figs. 9 and 24^a) or in twos to a slender peduncle (*pd*); but often three or four constitute a colony. A group of these monads, seated on their short pedicels (fig. 8 pd^2), and the latter arising from a nearly common point at the end of a long, slender peduncle (fig. 8 *pd*), might be designated, in botanical parlance, as umbellate. Very seldom are more than four or five bodies assembled in one colony, but occasionally as many as eight (fig. 7) are united in a single umbel. They bear the same remarkable relation to each other and to the main stem (*pd*) that we find in *Anthophysa*, that is to say, the arcuate flagellum (*fl*) of every member of the group curves backwards towards the base of the common peduncle (*pd*); and consequently the rest of the organism of each one holds a corresponding position. When there are but three or four in a colony the longer axis of each monad usually diverges at an angle of not more than thirty or thirty-five degrees from the axis of the main stem, but when the number is greater the divergence is also greater, and frequently amounts to seventy or eighty degrees. Oftentimes it will be observed that several of a group of bodies are attached in pairs (figs. 21, 22) to the pedicels, instead of each being possessed of a support of its own. This, as will be explained more fully under the head of *fissigemmation*, arises from an incompleteness of the self-division of which the pairs are the several resultants; and it will be noticed also that they are smaller than those which arise singly from the common peduncle.

The usual *form* of the body is an oblique oval (figs. 25, 26, 27,) which is twice as long as it is broad; but in old individuals, which are about to undergo self-division, the shape is very broadly oval (fig. 24^a), and its one-sidedness is not very conspicuous. The same may be said of specimens which have lived for a while in stale water, and have lost nearly all their yellow color (fig. 24). Posteriorly it tapers, more or less abruptly, into the pedicel (figs. 25, 26, 27, pd^2); but anteriorly it is slightly constricted (b^2) a short distance behind the front, and thence projects in the form of a low, truncate cone (fig. 24^a *fr*). From the constriction (b^2) there projects, in direct continuation of the epidermis of the body proper, a very high *membranous, campanuliform collar* (b, b^1), presenting, on the whole, an appearance as if the body were seated in the lower half of a deep, urceolate calyx. That this collar is not the upper portion of an urceolus in any sense of the term may be demonstrated in two ways, at least. In the first place, it is highly flexible and retractile; as it occasionally shows itself to be, either by narrowing its aperture almost to absolute closure (fig. 24, *b*), or by reducing its height to a small fraction of its greatest altitude, — as seen in fig. 27, *b*,— and then extending itself again, within a few seconds, by a direct protrusion, (fig. 26, *b*) to its original proportions (fig. 25, *b*). In the second place, it divides longitudinally, like the rest of the body when self-division occurs (figs. 11–22), a process in which no genuine calicle was ever known to be concerned. In an adult state (figs. 8, 11, 24^a, 25) it is slightly constricted by a gradual incurvature extending from the base (fig. 24^a, b^2) to the distal margin (b^1); but frequently, and apparently always just before self-division takes place, its sides bulge slightly outward (fig. 11, *b*). Taking all these things into consideration, therefore, it is perfectly clear that this infusorian is not a calyculate form, but one of those mimetic shapes which occasionally deceive the eye and puzzle the observer, until he becomes familiar with their various phases of growth and development.

This phenomenon is most singularly exemplified by the creature before us now, in its almost indistinguishable resemblance to a genuine calyculate Flagellifer (*Salpingœca marinus*, figs. 28–32[a]) which abounds in our marine waters. This similarity arises chiefly from the fact that the urceolus (figs. 28–32, *c*) of the latter has an oval shape like the body of the former, and is constricted so closely at its aperture (c^1) as to present the appearance of being continuous with the high campanuliform collar (*b*) which projects from the front. Usually, however, the body proper of this animal (*Salpingœca marinus*, nov. sp.) lies loosely within, and considerably withdrawn (fig. 28) from, the parietes of its calyx; but occasionally, in older specimens, it completely fills (fig. 31) its sheath, and then it is next to impossible to distinguish it, in this respect, from a *Codosiga*. In a sessile, fresh-water species of *Salpingœca*, of the urceolate type (*S. amphoridium*, figs. 37–37[d]), the *resemblance* to *Codosiga* is almost as strong, but the *difference* is as equally marked.

The *flagellum* (figs. 8, etc., *fl*) is the only prehensile organ which *Codosiga* possesses. It arises from the middle of the low truncate cone (*fr*), which constitutes the front, and consequently within the campanulate collar (*b*); reminding one of the curvate *style* of a labiate, monopetalous flower. It is usually rigid, excepting at the tip, which is constantly occupied in throwing particles of various kinds toward the mouth (*m*) by vigorous, spasmodic incurvations, or jerks. At its basal half it is slightly curved toward the longer side of the body, but gradually reverses the arc and, assuming a much stronger bend in the opposite direction, terminates abruptly, and far beyond the edge (b^1) of the collar, with about the same thickness as at its base. It is a very conspicuous organ, and therefore its whole sigmoid length may be studied with any amount of detail that could be wished for. The plane of this sigmoid curve is a direct continuation of that which passes through the opposing longer and shorter curves of the obliquely oval body. Calling to mind now what has been said in regard to the direction of the curve of the flagellum of the respective individuals of the colony, it will be seen that if these planes are projected inwardly and downwardly, at the same time passing along the pedicels (fig. 8, pd^2) of each body, they will all meet at the main stem (*pd*).

Besides being used as an organ of prehension, the *flagellum* is occasionally devoted to other purposes; for instance, to act as a scavenger by whirling in a gyratory manner, and thus clearing the area, within the collar, of fæcal matters which have been ejected from the anus at a point near to, or perhaps coincident with, the mouth (*m*). At other times it acts as an organ of propulsion during the act of natation (fig. 23), when one of the resultants of self-division breaks loose from the colony and seeks another point to settle down upon and secrete its stem. During this wandering life of the monad it swims — at times very rapidly — with its basal end (fig. 23) preceding it in the direction of its course, and the *flagellum* (*fl*) following behind, and vibrating in rapid undulatory and gyratory curves, as if it were the screw propeller of some subaqueous vessel.

That the *mouth* (figs. 23, 24, 24[a], *m*) is situated near the base of the flagellum (*fl*) is rendered certain by the fact that particles of food are thrown by that organ directly against the area (*fr*) upon which it is based, and are taken within the body somewhere in that region; but, on account of the minute size of these morsels, and the rapidity with which they are swallowed, it has not been possible to determine precisely at what point The position of the *anus*, which, as I have already suggested, may possibly be coincident with the mouth, is easily determined, even to the narrowest limits, as the fæcal matter is discharged in large, highly refractile pellets (fig. 24ª, *d*), close to the base of the flagellum. The digestive vacuoles are quite conspicuous, and frequently very large; but they never have been observed to be so numerous as to obscure the view of the interior of the body.

The *contractile vesicles* (*cv cv*) are two quite conspicuous globular organs, which lie close to the surface, and in the posterior third of opposite sides of the body. Occasionally *three* (fig. 10, *cv*) of these vesicles are found together, but it has always been evident at such a time that the body was preparing for fissigemmation (figs. 9, 10), and that the increase in number of these organs arose from the fact that one of them had already undergone self-division. In another genus (*Salpingœca. S. marinus*, nov. sp. figs. 28, 29, 30) no less than *four* contractile vesicles (*cv*) have been observed to arise from two, under the same circumstances.

The systole of each vesicle of *Codosiga* occurs regularly once in half a minute, and usually that of one alternating with that of the other. Both the systole and the diastole proceed very deliberately, each, however, not occupying more than a few seconds. During the interval between the end of the diastole and the beginning of the systole the vesicles have a rather irregular, indefinite, spheroidal outline, but just at the moment of systole they assume a sharply defined and perfectly globular shape, and raise the surface of the body into a quite perceptible bulge. During this momentary expansion a vesicle equals at least half the greatest diameter of the body.

The *reproductive organ* — if we are not mistaken in our interpretation — is seated at the posterior end of the body, behind the contractile vesicles. It is a globular, highly transparent body (figs. 23, 24, *n*), and sometimes almost fills the space on each side of it. That it is solid, and not a mere vacuole, appears conclusive from its resilient action after being indented by the expansion of the contractile vesicles. It should be mentioned that this body was not observed in the fresh specimens which were collected in December, but appeared to be constant in some stale examples which had been kept on hand for two or three months.

The *peduncle* (fig. 8, *pd*), or main support of the colony, and the pedicels (pd^2) or immediate bearers of the individuals, share in the general gamboge yellow color of the latter, and also in their vitality. The latter statement has been verified fully in regard to the pedicels, by seeing them split down to their bases after the body proper has undergone self-division; and in regard to the peduncle, although only one observation was made, and the splitting was followed in its slow course downward for only a short distance, it was evident, from its much more than usual thickness, and the presence of a distinct median furrow which extended to its very base, that it eventually would divide into two stems. The length of the peduncle varies from a mere disc, when it begins to develop from the base of some newly settled monad, to five or six times the length of an individual. It always carries a single body until it is at least three or four times its length (figs. 9, 24, 24ª), and frequently much longer; but in the latter case it was sometimes observed to arise from the falling away of one of the resultants immediately after self-division occurred. It has a uniform thickness, or occasionally the slightest possible taper, from base to apex; and appears to be solid and homogeneous in texture. It is apparently inflexible, and even when carrying a single body is united to it at a sharp angle with the longer axis of the latter (fig. 24ª).

Fissigemmation. This is the only process of reproduction which has been observed. Several instances of this kind were partially followed through in an incidental way, and two complete courses were carefully noted and drawn within a half hour of each other. The set of figures 13, 15, 17, 19, 21, relate to one individual, and figures 11, 12, 14, 16, 18, 20, 22 to another belonging to the same colony. The rate of progress of the former when the drawings were made was not noted, but that of the latter set was observed in four out of six of the intervals which occurred between the phases which the figures represent, and during the progressive steps of the latter it was carefully recorded which of the successive stages of the former filled the intervals between those of the latter; so that it can be said, in the strictest sense, that all of the figures of both sets of observations represent the phases which were distinctly marked in the second series. In this way the fullest illustration possible was obtained, and no point was left unexplained. The whole time occupied by the process in the second series was *forty minutes.* It has already been mentioned, when describing the form of the collar, that it assumes a bulging, campanulate outline (fig. 11, *b*) as a preparatory, preliminary act in fissigemmation. In addition to this it should be stated that it widens inordinately at the distal end, so as to exceed, by one third, its normal breadth; but before it finally settles itself into this shape and proportions it contracts and expands its diameter by a peculiar sort of vibrating motion, and passes through a series of changes of form which vary from funnel-shape to a narrower cylindrical outline, or from either of these to a broader cylindrical proportion, such for instance as figures 9 and 10 — representing the same individual — exemplify. This would appear also to be the time when the contractile vesicles divide, for at no other period were they observed to be more than two in number, as they are represented in figures 9 and 10 (*cv*).

Immediately after this preparatory sign was discovered, — the time being noted at 12.55 P. M., — the flagellum became unusually conspicuous, and much thicker, and moreover it lost its sigmoid flexure and assumed a perfectly straight carriage, with the slightest possible tremulous, vibratory motion. Within a very few minutes after this the flagellum began to shorten as if retracting, — reminding one of the running down of a cotton thread in the flame of a candle, — and in one minute's time it became reduced (fig. 12, *fl*) to a length which was somewhat less than half the height of the collar (*b*), and then it rapidly disappeared, and left no trace of its former position. During this process the body shortened and became broader (fig. 12), in the same direction that the plane of the arc of the flagellum formerly trended in, and consequently the contractile vesicles (*cv*) were more widely separated; and, the front (*fr*) also having become proportionately extended laterally, the base of the collar (*b*) was also increased in diameter until it almost equalled that of the distal end, so that, as a whole, it was almost cylindrical.

In less than fifteen minutes after the preparatory stage was observed, the collar had become cylindrical (fig. 13, *b*) by a combined action of the base and distal end, which consisted in a narrowing of the latter and a broadening of the former.

It was not until 1.15 P. M. that a decided mark of incipient self-division became evident in the guise of a narrow, slight furrow (fig. 14, *e*), which extended, medianly, from the front to over half way toward the posterior end of the body. By this time the body had broadened until it was wider than long, and the collar (*b*) — having followed this expansion at its basal portion whilst its upper extreme had contracted a little — had assumed the form of a high, truncate cone.

In two or three minutes after this the body had become distinctly indented (fig. 15, e^1) at the anterior termination of the furrow (fig. 15, *e*), and the latter had grown longer and more distinct, whilst the collar (*b*) had approximated more closely in shape to a perfect cone.

In another minute or two the anterior indentation (fig. 16, e^1) had become so deep and broad that the body presented a cordate outline when seen from its broader aspect, whilst the furrow (*e*) appeared to extend to its base, and the distal end of the collar (*b*) had so nearly closed up as to give that body an almost complete conical form, with a slightly collapsed periphery.

From this moment the process of reduction ceased, and soon after the cone-shaped collar began to expand (fig. 17, *b*). Consentaneously with this, the anterior indentation (e^1) had become sharper and deeper, and, — with the lateral median furrow (*e*) of each of the opposing broad flanks of the infusorian acting in combination with it, — had split the body about half way to its base. The most remarkable phenomenon observable at this time was what occurred at the rounded ends of the two half separated bodies of the new pair of individuals. This was no more nor less than the incipient development of the flagellum, which proceeded in this wise. At each of the rounded ends just mentioned a slight commotion appeared, resembling the molecular vibrations of a granule, and then there arose quite rapidly a sharp and distinct filamentous outgrowth (*fl*), which kept itself in a constant state of narrow vibrations, or a sort of shivering.

By 1.23 P. M. the newly born flagella (fig. 18, *fl*) had risen to half the height of the collar (*b*), and still remained in a shivering condition, whilst the body had divided almost to its base, and the collar had broadened to a widely terminating, truncate cone.

In about a minute more the dividing process had risen into the collar and split it (fig. 19, e^2) upwards for one quarter of its height, and the still tremulous flagella (*fl*) were slightly longer than in the last phase.

By 1.26 P. M. the body was divided (fig. 20) to its posterior termination, and the fissuration (e^2) of the collar (*b*) had reached half way to the distal edge, and was further sketched out, as it were, by two opposing shallow, longitudinal furrows which extended to the margin. At this period the collar was broader at the still undivided portion than below, so that on the whole it had a very wide campanuliform shape, or rather, — since the divided portion was rolled inwards at the opposing edges, — was like two slightly flaring broad funnels, merged into each other at their broader ends. The flagella (*fl*) also had developed considerably, and extended a short distance beyond the collar; and the front end of the body, from the middle of which the flagellum arises, had assumed the low, truncate, conical shape of the adult form.

From this time onward the division did not appear to go forward so rapidly, and the new bodies seemed to be more particularly occupied in shaping themselves into the characteristic form of the adult. The collar, however, was not long in dividing itself up to its margin (fig. 21), but still the two cylindrical halves (*b, b*) did not separate at their extremes as soon as the fissation reached that point.

At 1.35 P. M. the self-division was completed (fig. 22) as far as the body proper was concerned, and had extended a short way down the pedicel (pd^2). The margins of the two collars (*b*) seemed merely to lie in contact, and each collar had a slightly funnel-shaped outline, and was considerably more elevated in proportion to its diameter than in the adult form. The flagellum (*fl*) was nearly as long as that of the full-grown body, but yet had neither the sigmoid curve of the latter nor its stout and rigid aspect, but was much more delicate, and in fact still exhibited a slight, tremulous motion. The two contractile vesicles (*cv*) of each body were as distinct as those of the adult, and had the same proportionate size and relative position.

In a very few minutes the two resultants were totally separated and divergent from each other at a sharp angle, and in less than half an hour after the last time noted they had assumed the proportions of the other members of the colony. Shortly after the investigation of the phase just described, the last stages of self-division of another body, belonging to the same colony, were observed, and thus the group, which within two hours before consisted of five individuals, was increased to eight (fig. 7). It seems to be a rare occurrence that so many bodies remain long together, since it very seldom happens that more than four or five (fig. 8) are found in a colony; and now and then, in such instances, I have seen an individual drop off and swim away. When we meet with them settled down upon some point, amidst others which have scarcely any stem, and those which are seated on very short peduncles, it becomes perfectly clear that they are there for the purpose of secreting a new support from the posterior end.

§ 7. Salpingœca,[1] nov. gen. (S. gracilis, nov. sp.)

(Plate IX., figs. 38, 39.)

The difference between this genus and *Codonœca* has already been pointed out. It might well be compared to a stemless *Codosiga* (§ 6) enveloped in a sheath. I have met with three quite diverse species of this genus, of which that under present consideration and another (*S. amphoridium*, nov. sp. § 9) are fresh-water denizens, and the third (*C. marinus*, nov. sp. § 8) is a marine inhabitant. *S. gracilis* (figs. 38, 39) was found upon only one occasion, and then in an old aquarium, which could not be said to be in a perfectly healthy condition, although its contents were by no means putrid.

The *body* is yellow and has a cylindrical shape, about four times longer than broad, narrowed and rounded behind, and rounded-truncate in front. Like *Codosiga* it bears a filmy, membranous, colorless collar (*b*), which is attached to the extreme edge of the frontal area (*fr*), and arises to a height which is equal to two thirds the length of the body. The outline of the collar is cylindrical, as a general thing, and truncate at the distal end, but still is subjected to various degrees of momentary change. Unless it be by means of the vibrations of the flagellum, there is no other immediate agent which can be supposed to move the body up and down in its sheath. There is no visible movement in itself, like creeping, to be observed, and moreover the body progresses so quickly, when changing its place in the calyx, that it becomes evident that it is not due to any reptant mode of transposition. When withdrawn (fig. 38) into the basal, tapering portion of its calyx, the collar (*b*) does not extend beyond the rim (c^1) of the latter, but on the other hand the body occasionally moves so far in the opposite direction (fig. 39) that nearly the whole of the collar (*b*) projects outside of the dormitory.

The *flagellum* is a delicate filament, which arises from the axial point of the front and projects a short distance beyond the edge of the collar. It presents a constantly undulating aspect, and vibrates from base to tip.

The *mouth*, we are obliged to presume, as we did in regard to *Codosiga*, lies somewhere about the base of the flagellum. Abundant digestive vacuoles were observed, as well as loose particles of food, in various parts of the body; but at no time were we so fortunate as to see the introception of nutritive material, or the ejection of fæcal matter.

[1] σάλπιγξ, a trumpet; οἰκέω, to inhabit.

The *contractile vesicles* (*cv*) are two in number. They lie between the second and posterior thirds of the body, usually on opposite sides, and close to the surface. In aspect and rate of systole they resemble those of *Codosiga pulcherrimus*, but they are a little smaller in proportion to the size of the animalcule. Sometimes the protean changes of the body are so extensive as to throw the two vesicles into line with each other in an antero-posterior direction, but they hold this position only temporarily, and soon return to their normal relations.

The *calyx* (c, c^1, c^2) has the general shape and proportions of a champagne glass, and appears to be hollow to the very bottom (c^2) of its pedicel-like, inferior third. Anteriorly it is truncate, smooth, and flares (c^1) quite strongly. About the middle it bulges very sensibly, and thence tapers gradually into a slender posterior third (c^2), but expands again slightly as it terminates upon its place of attachment. It is colorless, excessively transparent, and exhibits considerable flexibility under the movements of the body; apparently having the consistency of a mere film.

§ 8. Salpingœca marinus, nov. sp.

(Plate IX., figs. 28–32^a.)

The remarkable generic resemblance of this species to *Codosiga* has already (p. 315) been commented upon. It is very common, especially upon the marine Hydro-Medusa, *Dynamena pumila*. Lamx., but is so excessively minute, and withal so transparent, excepting the body proper, that under a magnifying power of five hundred diameters it appears to the casual observer like a mere globular speck. It was discovered when searching after specimens of *Codonœca costata* with a power of eight hundred diameters. Although sometimes met with in groups of forty or fifty, it always appeared single. In its general aspect it may be compared to an oval flask which is supported by a slender stem (*pd*), and has a broad funnel inserted in its mouth. Upon close inspection we find that the funnel (*b*) is a direct projection from the body which hangs freely within the flask (c, c^1,), and is in no way connected with the latter.

The *body* proper has a dark fuscous color, and consequently is quite conspicuous. It is mainly oval in shape, but is constricted anteriorly into a short thick neck (*i*) which terminates in a truncate front. It hangs quite loosely within the calicle (*c*), and usually at a considerable distance from its parietes, but at the mouth (figs. 31, 32, c^1) of the latter the neck (*i*) presses so closely against it as to seem, without the most careful scrutiny, to form a continuation with it. Occasionally, however, the neck narrows and retreats from the aperture of the calicle to that degree which allows a clear and unmistakable view (fig. 32) of the relations of the former to the latter.

The *collar* (*b*), which has just now been likened to a funnel set in the mouth of the flask-shaped calyx, is most frequently seen in a very broadly expanded state (fig. 28, *b*); in outline resembling a low, obtuse-angled, truncate cone inverted upon the front of the body. It arises from the extreme circular margin of the head (*i*), and, widening to about twice the equatorial diameter of the calyx (*c*), terminates in a smooth edge at an altitude which is hardly equal to one quarter of the width of its distal expanse. It is hyaline, and so extremely thin and filmy as to require the most careful manipulation of the light, even with so high a power as eight hundred diameters, in order to define its boundaries clearly. Its plasticity is even more marvellous than that of *Codosiga;* at least it is exhibited over a far wider lateral range than in the latter, and with equal rapidity in its changes. In a few seconds it narrows from its greatest expanse to the proportions of an obverted, acute-angled cone (fig. 29, *b*), and at the same time assumes an altitude which is equal to the length of the body; and then, within an equally short period, it contracts into the form of a cylinder (fig. 30, *b*) whose height more than equals that of the calyx. These changes are carried on with the same peculiar vibrations as were noted in regard to *Codosiga*, reminding one of the glimmering outlines of the prongs of a tuning-fork when vibrating. When observed with a poorly defining lens, I can readily see that this phenomenon might be mistaken for the cone of light produced by the gyratory vibrations of a single filament, or for the bright *lumen* of a circular row of vibrating cilia. As regards the former category it may be said that the flagellum is far more conspicuous than the collar, and may be seen clearly projecting in the line of the axis of the body, and vibrating after a manner of its own. As for the latter supposed case, one might be inclined to dismiss it without any scruple, upon the simple assumption that no flagellate infusorian can bear numerous cilia, were it not that I call to mind my own discovery of a flagellated animalcule (*Heteromastix*, figs. 70–74) of the heteronematous form, which is at the same time abundantly ciliated. I have, therefore, taken all possible pains to ascertain that this "*collar*" (figs. 28–32, *b*) is a genuine membrane, and not the similitude of one.

Occasionally individuals (fig. 32) were seen which bore an inverted conical collar (*b*), that remained — at least for a time — at an expansion and altitude equal to the breadth and height of the calyx (*c*). These were among the largest specimens found, and almost or altogether filled the calyx. Rarely were examples found which crowded the calyx so fully as to seem to bulge it out laterally. Figure 31 represents such an instance, in which the aperture (c^1) of the calyx is absolutely inseparable from the head, excepting that, knowing that it is not really continuous, one recognizes the line of demarcation by the abrupt change in the thickness of the seemingly uninterrupted membrane. This case is also remarkable, inasmuch as it at the same time furnishes us with an example of an enormously large, bulging, campanulate collar, nearly as broad as the most common and normally permanent form (fig. 28), and yet higher than it is wide. In all probability, judging from appearances, which in every respect remind one of the preparatory steps of fissigemmation of *Codosiga pulcherrimus*, this individual is soon about to undergo self-division. Unfortunately the drawing was made at a time when the impending process could not be watched.

The *flagellum* (*fl*) is as highly flexible as that of *S. gracilis*, and very active throughout its length. It is attached to a more or less elevated axial prominence in the middle of the frontal area, and extends to a length which is, at most, not more than one third greater than that of the body.

Regarding the *digestive organs* nothing can be said, excepting that dark irregular pellets and loose foreign material were abundant enough, and so irregularly scattered that they could not be looked upon otherwise than as nutritive matter.

The *contractile vesicles* (*cv*) are two or three globular bodies, which in appearance, position, relative size, and rate of systole, may be compared with those of *Codosiga pulcherrimus*. On one occasion (fig. 30), they amounted to four (*cv*) in number, and were arranged in pairs, one above the other.

The *calyx* (c, c^1) usually has the form of a Florence flask, but with a very short, thick neck, which flares (c^1) slightly at the aperture. It sometimes, however, is slightly pointed at its base where it joins the pedicel (*pd*). When not filled by the head (fig. 32, *i*) of the animalcule, the neck and the sharp margin (c^1) of its aperture may be clearly distinguished from the collar (*b*) which rises just above them; but very frequently this discrimination is attended with a good deal of difficulty, because when the body presses closely at this point it overlaps the margin in question, and obscures it. The pedicel (*pd*) is not much longer than the calyx, and joins the latter with little or no expansion. It is colorless like the calyx, moderately slender, of a uniform diameter from top to bottom, and appears to be solid and homogeneous in texture. Figure 32[a] represents one of three bodies which were found in the midst of several living animals of this species, and which had every appearance of being the deserted calicles of the same, with a collapsed aperture. In the next species (*S. amphoridium*) the deserted calicles (fig. 37, *c*) were found so numerous among those which were occupied, and moreover retaining the shape of the latter so perfectly, that there could be no doubt that the calyx is not only a separate organism apart from the body-wall, but also may be as readily vacated as that of *Cothurnia* or *Vaginicola*.

§ 9. Salpingœca amphoridium, nov. sp.

(Plate IX., figs. 37–37[d].)

Although this species bears a strong resemblance to *S. marinus* (§ 8), there are several prominent points of difference between the two. *S. amphoridium* is a fresh-water form, and appears especially to frequent old specimens of *Zygnema* and other filamentous *Algæ*. It is very common in such places, and lives in more or less crowded groups. Excepting the main part of the body it is very transparent, but not so faint as *S. marinus*. It varies much in size, even down to half that of fig. 37[a]. Like its marine congener it always occurs single, and never with a trace of a pedicel to the calyx (c, c^1). As a compensation for this, if one may use the expression, it has a long neck, which is frequently seen bending from side to side (fig. 37[b], *i*) with a gentle motion, and apparently in search of something.

The *body* is gray or greenish yellow in color, which fades in the neck (*i*) and disappears altogether in the collar (*b*). In its general aspect the body, with its collar, might be compared to a wine-glass with a long stem and a globose pedestal. The globose part is the posterior half of the body, and the stem is its neck, or anterior half, which tapers rapidly from the main part to one quarter or one fifth its diameter, and then gradually widens to nearly double that thickness at its front, where the collar is set on. The *front* is truncate, or rises into a low cone, upon which the flagellum (*fl*) is based. The posterior half of the body usually fills the bottom of the calyx (*c*), but the rest and the neck (*i*) stand off from it at a very appreciable distance. In this respect there is a marked difference between this species and *S. marinus* (§ 8). In the latter we might say that the body is suspended from the aperture of the urceolus, but in the former it rests on the bottom of the calicle. Not infrequently, however, the whole body of this species lies loosely within its calyx (fig. 37).

The *collar* (*b*) is an excessively hyaline, filmy membrane, whose distal margin (b^1) is so extremely delicate as to almost defy detection with the highest powers. In the latter respect it is a more difficult object of research than that of *S. marinus*. Generally speaking it may be described as obconical, but with greatly varying degrees of width. In this relation it agrees perfectly with that of *S. marinus*, and therefore need not be redescribed here. At its greatest height it equals that of the body, and always terminates in a smooth edge. Its plasticity is also equal to that of the marine species. In one instance, when the animal was disturbed by a predaceous Rotifer, its whole body quickly retracted, and the collar totally disappeared, as if melted down with great rapidity; but soon after protruded slowly, at first with a broad base (fig. 37^{d}, *b*), and then rapidly narrowed at the latter point and assumed its usual proportions.

The *flagellum* (*fl*) differs from that of *S. marinus*, both in proportions and deportment. It is usually rigid and projects considerably beyond the collar when the latter is at its greatest height. It has a decided arcuate figure, with a uniform thickness throughout, excepting near the base, which tapers rapidly from the low cone in the middle of the front. Its apex moves with quite gentle, spasmodic twitches, and the whole becomes flexible (fig. 37^{b}, *fl*) when fæces are ejected, or some undesirable particle enters the area within the collar.

The *mouth* was not actually seen; but that it exists somewhere about the base of the flagellum was sufficiently demonstrated by seeing minute particles of food thrown by the latter organ against the front, and rapidly disappear there. The *anus* (fig. 37, *a*) certainly opens within the same area, as particles of considerable size were seen to make their exit at the base of the flagellum. No digestive vacuoles were noticed, although the body was often found filled with food.

The *contractile vesicles* (*cv*) usually amount to three or four, and rarely to five in number; or there are two very large ones, which occupy nearly the whole breadth of the body (fig. 37^{a}). They occur in all parts of the body except its neck, and beat with a sluggish systole about at the same rate as those of *Codosiga* (§ 6).

The *calyx* (*c*, *c*^{1}) has very much the same proportions as the body over which it is fitted as if upon a mould. Its posterior half (*c*) is globular, and is attached at its hindermost, axial termination to the point of support. Although hundreds of specimens of this species were observed, not one of them had a pedicel. The anterior half tapers, like the thick neck of an urn, from the posterior one to one third its diameter, and then rapidly widens and terminates with a flaring, smooth-edged aperture (*c*^{1}), which is about twice as wide as its narrowest portion. The margin usually is exceeded by the projecting head, so that the former may be seen quite readily as a distinct ring behind the circular edge of the front from which the collar rises. The empty calicles (fig. 37^{c}) were found very frequently, and so nearly identical in form with those of the living body that they must have possessed considerable rigidity. That they are, however, to a certain degree flexible and plastic, was shown on one occasion when the body and neck suddenly retracted and swelled laterally (fig. 37^{d}) to an extent which was considerably beyond the usual breadth of the calyx and its neck, and then returned to its former shape and proportions.

§ 10. Leucosolenia (Grantia) botryoides, Bowerbank.

(Plate IX., figs. 40–44. Plate X., fig. 64.)

If I were now to describe merely the congregated monads of this compound animal without giving it a name, any one who had already become acquainted with the structure of *Codosiga* (§ 6) would set down the first as a colonial, massive form of the latter. In fact, a glance at a figure of a free swimming individual (fig. 23) of *Codosiga*, in one of its numerous attitudes, and then a momentary inspection of the monad (figs. 42, 43, 44) of this sponge would almost induce one to believe that the two belonged to the same genus, nay, even to the same species, as far as the representations referred to are concerned.

In the introductory section of this memoir I have already discussed the theory of Carter as to the alliance of Sponges with Rhizopods; and I will therefore only state here my firm conviction that the true, ciliated *Spongiæ* are not *Rhizopoda* in any sense whatever, nor even closely related to them, but are genuine, compound, *flagellate Protozoa;* and are most intimately allied to such genera as *Monas* (§§ 1, 2), *Bicosœca* (§§ 3, 4), *Codonœca* (§ 5), *Codosiga* (§ 6), and *Salpingœca* (§§ 7, 8, 9). What are the special relationships of the numerous genera of Sponges, I am not prepared to say; yet in regard to *Leucosolenia botryoides*, there can be no doubt that it is very closely allied to *Codosiga* and *Salpingœca*, but to which one more than to the other would be difficult to determine. *Codosiga* (§ 6) is a compound form like *Leucosolenia*, and its individuals are united by a common, branching support, which has been shown, by the changes which it passed through during fissigemmation, to be as fully alive as the glairy, spicule-secreting cytoblastema of the Sponge. *Salpingœca* (§§ 7, 8, 9), on the other hand, is a single monad, but excretes around it an envelope, or *calyx*, into which the body is sunken in the same way that the monads (fig. 41, *md*) of the Sponge are imbedded in the surface of their common dormitory. Inasmuch, however, as the calyx is probably an excretion rather than a secretion, and appears as inanimate as that of *Cothurnia*, *Vaginicola*, and other *Vorticellidæ*, it is more comparable to the *spiculæ* (*sp*) than to the *cytoblastema* of Sponges. If one may draw an inference from the above considerations, it does not seem at all improbable that hereafter we shall find that the monads of the different genera of Sponges resemble the various genera of single and branching Flagellata, and then we will be able to divide the former into such family groups as *Monadoidæ*, *Bicosœcoidæ*, *Codosigoidæ*, *Anthophysoidæ*, &c. &c.

Leucosolenia botryoides, Bowerbank, occurs on our sea-shore among the groups of *Dynamena*, *Sertularia*, &c., and may be readily recognized by its ivory-white color. The colony is an elongate mass, and seldom exceeds more than an inch or an inch and a half in length, and resembles an irregular group of slender, contorted spines or forked horns (fig. 40), which vary in thickness from one thirtieth to one sixteenth of an inch in diameter. At the tip of each horn is an aperture — the so-called excurrent orifice — large enough to be seen by the unassisted eye. The whole mass is so transparent that not only the currents in the interior, but even the vibrating flagella and the pulsation of the contractile vesicles may be seen with a strong light. The exterior consists of an excessively hyaline, cytoblastematous layer, with scarcely, if any trace of organization of a cell-like character in it. Within this layer, or immediately beneath it, but certainly not in the monadigerous stratum, the faint yellow *spicula* (fig. 64, *sp*, *sp*¹) are imbedded in systematic order, and overlap each other irregularly in two or three layers. They present two diverse forms, namely, a simple aciculate shape (*sp*¹), and a stellato-tri-radiate (*sp*) one. The rays of the latter are slender, tapering frequently to a bifid termination, divergent at equal angles from each other, and lie in the same plane. Without exception they are all arranged with one ray — often longer than the others — projecting backwards, *i. e.*, away from the excurrent orifice, and the other two extending symmetrically right and left, and obliquely transverse to the longer axis of the branch. In this manner they are disposed in a sort of net-work over the whole colony, even close up to the excurrent orifices; and as the aciculate spicula lie parallel with the rays of the other kind, there are consequently no projecting spines specially devoted to guarding the entrance to these apertures.

The *ostioles* (fig. 64, *o*), or incurrent channels, are very numerous, there being at least two, and often three, opposite every interstice of the spicula. They are very small, but quite conspicuous, especially at their inner ends, where they plunge through the monadigerous layer (*md*). They afford great assistance whilst studying the contractile vesicles, and the action of the flagella, since they enable one to get a freer view of the monads, in an undisturbed state, than where they are observed through all the tissues. It should be mentioned, however, in this connection, that the profile view (fig. 41) of the monads was obtained by making an actual section of one of the younger branches and allowing it to revive and expand in a fresh supply of sea-water.

The *monadigerous layer* (figs. 41, 64, *md*) lines the cavity of the body; and it is by the combined action of the vibrating flagella (*fl*) of the monads that currents of water and floating particles are kept up. This layer is composed of monadiform animalcules (*md*), packed closely side by side in a vast colony, which extends over the whole length and breadth of the general mass. In this respect we are reminded of the similar arrangement of the individuals of that floating ascidian *Pyrosoma*. These monads crowd so closely upon each other that their sides are mutually compressed, and they thus form a sort of irregular, polygonated pavement (fig. 64, *md*). They all lie with the anterior end (*fr*) turned inwardly, and projecting into the general cavity, and the posterior extremity imbedded in the cytoblastematous external, general envelope.

The *body* of a monad is yellow when seen by transmitted light, and in general terms may be designated as broadly oval, with the longer axis extending antero-posteriorly. Behind it is broadly rounded; at the sides lightly indented and irregularly polygonal by mutual contact with others; and extended in front into a delicate, membranous, circular collar (b, b^1), which might be compared to a transverse section of a tube which is about as long as it is broad. This *collar* is capable of variations in form, like that of *Codosiga* (§ 6) and *Salpingœca* (§§ 7, 8, 9), at one moment assuming a truncate conical shape (figs. 43, 44, *b*), and in the next instant expanding its distal margin into a distinct flare (fig. 42, *b*) which is at least two thirds as wide as the body; or, finally, it retracts altogether and disappears for a while, but eventually reappears, and expands to its fullest dimensions.[1]

The *flagellum* (*fl*) is the only prehensile organ which the monad possesses. It arises from the middle of the frontal area and extends to a great length, at least five or six times as long as the body, with scarcely any diminution in thickness. It is a comparatively thick filament, and quite conspicuous; on which account it is so easily seen through the whole mass of the colony. It usually vibrates with considerable vigor from base to tip, but occasionally assumes the quiescent state, and arcuate form so eminently characteristic of that of *Codosiga* (§ 6), *Bicosœca* (§ 3), and others.

1 In this connection it may be well to mention the latest decision of Carter in regard to the structure of the monociliated sponge-cell. In the Annals and Magazine of Natural History, Vol. xx. 1857, Pl. 1, figs. 10, 11, this cell is represented as an oval body, with a single ciliary appendage; but in a subsequent communication to the same periodical (Vol. iii. 1859, p. 14, Pl. 1, figs. 12, 13, 14,) a partial recantation seems to be made, and the cell in question is figured with "two spines or ear-like points projecting backwards, one on each side of the root of the cilium." If now we suppose these "*two spines*," to be the right and left profiles of a membranous, cylindrical collar, such as I have described in *Leucosolenia*, then it follows that the monociliated sponge-cell of *Spongilla* is like that of the former. That Carter did not always find these "two spines," may be explained by the fact that the membranous collar, as I am inclined to believe the "spines" to be, was retracted; since I have frequently observed this to happen in the case of *Leucosolenia*, when it was disturbed.

The *mouth* is the only organ which has not been actually observed, although its position has been inferred, not only from the otherwise similar structure of the monad of this creature to that of *Codosiga* (§ 6), but because currents of floating particles are constantly whirled in by the flagella and made to impinge upon the area within the collar. In addition to this it may be added that more or less numerous coarse and fine particles (fig. 44, *d*) are always present, and scattered irregularly about the interior of the monads, apparently under various degrees of digestive decomposition.

The *contractile vesicles* (*cv*) are two in number, and lie near each other, at or about the middle of the body. When fully expanded they are from one fifth to one fourth the diameter of the monad, and have a perfectly globular shape. In appearance, and manner and rate of systole and diastole they resemble those of *Codosiga* so closely that the former might be substituted for the latter with scarcely a chance for a detection of the change. As the rate of systole of each vesicle, which is once in half a minute, was observed directly through the undisturbed layers of the colony, and moreover at the edge of the ostioles, there need be no hesitation in accepting the record as that of the normal measure of pulsation.

§ 11. Anthophysa Mülleri, Bory.

(Plate X., figs. 47–63.)

A description of this infusorian — but without illustrations — has already been sent for publication to the "American Journal of Science," and will appear in its September number. In order to carry out the object of this memoir to its fullest extent, I propose here to make quite large extracts from this paper, and also to add a number of figures, both for the better understanding of the character of the animal, and for the sake of comparison with others, which are illustrated in the accompanying plates.

The mononematous *Flagellata* which are described in the foregoing pages (§§ 1–10), are connected with the heteronematous forms through two diverse lines; or rather they are closely allied to two different types of *diversiflagellate* infusoria, of which *Anthophysa* is an example of one type, and *Anisonema* (§ 13) a representative of the other; both of the *flagella* of the former being proboscidiform, and of the latter, one being gubernaculiform and the other proboscidiform. The intimate alliance of *Anthophysa* with *Monas* may be best expressed by saying that the former is a *Monas* modified by the addition of a comparatively minute *cilium* which is affixed to the head near the *flagellum*.

Anthophysa Mülleri, Bory (Epistylis? vegetans, Ehr.) is quite common among fresh-water plants, such as *Myriophyllum*, *Ceratophyllum*, and *Utricularia*, and adheres to their filiform leaves like an irregular, floccose, brownish deposit.

"Under a low magnifying power this floccose matter appears to consist of clusters of very jagged, irregularly branching and contorted, semi-transparent, intertwined stems and projecting, tapering, and flexible twigs (*pd*). Each of the tips of the latter sustains a single, more or less globose mass of spindle-shaped bodies (*md*), which radiate from a common centre of attachment, and are kept in a constant agitation by the spasmodic jerks of a long, stout, usually rigid, arcuate filament (*fl*), with which the free end of each one is endowed. The whole bristling mass revolves alternately from right to left, and from left to right; whirling upon its slender pivot with such a degree of freedom that one might almost suspect that it merely rested upon it, and had no truer adhesion to it than the juggler's top to the end of the *baton* upon which it spins. The largest of these twirling groups contains as many as fifty fusiform bodies, but most frequently not more than half that number are grouped together; and from this they vary in decreasing numbers down to only one or two (fig. 48), upon each filamentous twig. In the last instances the bodies are comparatively quiet, scarcely moving out of focus at each spasmodic twitch of the arcuate filament. On this account, and because they offer an unobstructed view, the latter are by far the most available as objects for the investigation of their internal organization."

"The relationship of the individual monads to the whole colony must, however, be studied where they are more numerously congregated; since, as will be shown presently, each monad sustains a definite relation to every other one, and to the twig to which it is attached."

"*Form, &c.* — The adult monads (figs. 47, 48, *md*) have a truncate fusiform shape, and are slightly, but quite appreciably flattened on two opposite sides; so that in an end view they appear to be broadly oval transversely. The attached end tapers gradually to a point; and on this account it is difficult to determine where the body ends and the twig begins. All of the members of a group radiate from a common point of attachment, to which they adhere by their tapering filamentous ends (fig. 48, pd^1). The free end is truncate, but one corner of it — as if in continuation of the line along which the opposite flattened sides meet — projects in the form of a rather blunt triangular beak (*lp*). At the inner edge of the base of this beak lies the mouth (*m*), to which the former — as frequent observation has proved — acts as a lip or prehensile organ when food is taken into the body. The prevailing tint is a more or less uniform light gamboge, without the least trace of an eye-spot of any color."

"A most singular uniformity prevails in the arrangement of the several members of a group. Each monad (*md*) is attached to its mooring in such a position that its flattened sides lie parallelwise with those of its nearest neighbor; and the beak (*lp*) projects from that corner of the head which is most distant from the twig (*pd*). To give a full idea of the peculiarity of this arrangement it must be stated here that the rigid, arcuate, spasmodically twitching filament (*fl*) mentioned above, is attached close to the mouth (*m*), and invariably curves away from the beak, and consequently always toward the pedicel (*pd*) of the colony."

"*Prehensile organs.* — The only motile organs which this animalcule possesses are preëminently prehensile in character; and their apparent appropriation for the office of propulsion, when a colony breaks loose from its attachment, I can scarcely doubt is an accidental one, inasmuch as the arcuate cilium continues its spasmodic twitching without any apparent deviation from its usual mode of action."

"There are two cilia, of very unequal size, attached to the truncate end of the body. The larger one of these has already been mentioned casually, as a *rigid, arcuate filament* (*fl*). It does not taper, but has a uniform thickness from base to tip, and is about half again as long as the body. It arises near the base of the triangular beak (*lp*), but appears to be separated from the latter by the intervening mouth (*m*). When quiet it appears like a bristle, and projects in a line with the longer axis of the body; at the base bending slightly toward the beak, and then sweeping off in a moderate but distinct curve in the opposite direction, so that on the whole it presents a long-drawn-out sigmoid flexure. The plane of this curve lies in strict parallelism with the plane of the greater diameter of the body; in fact it may be said to be a direct continuation of it. It does not appear to have the character of a *flagellum*, except when assisting the smaller cilium (*fl*[1]) to convey the food to the mouth, and then it lays aside its rigid deportment and assumes all the flexibility and wavy vibration of the prehensile organ of an *Astasia*."

"*The smaller cilium* (*fl*[1]) is an excessively faint body, and almost defies the detective powers of the highest objectives. This is partly due to its almost incessant activity; for when it is quiet, or nearly so — which happens when food is passing into the mouth, — it becomes comparatively quite conspicuous under a one eighth of an inch objective. It is scarcely as long as the greater diameter of the truncate end of the body. It arises close to the base of the larger cilium (*fl*), but whether on the right or left, or nearer or more distant from the mouth than the latter, cannot be said positively. Most frequently it was observed to be flexed in the same direction as its companion; and occasionally it seemed to be quite evident that it was attached nearer to the mouth than the latter. It is highly flexible, and vibrates with great rapidity in what appears to be a gyratory manner."

"*The Mouth.* — This organ is never visible except when food is passing through it (figs. 50, 51, *m*). It then may be seen that it lies close to the beak, which acts as a sort of lip by curving over the introcepted particles as they pass into the body. The mouth is highly distensible; at times allowing particles as wide as two thirds the greater diameter of the body to pass in without any apparent extra effort (fig. 51, *m*). It seems undeniable that it possesses discriminative powers in regard to the quality of its food. This one may readily judge of for himself, by seeing the unerring precision with which the particles of floating matter are thrown, by the spasmodic incurvature of the larger flagellum, against the mouth, where, if they are not swallowed, they are detained but for an instant by the smaller cilium, quickly adjudged to be worthless, and then thrown off with a twirl of the organ which held them in temporary abeyance. If, however, the captured morsel proves to be agreeable, the larger cilium (fig. 47, *fl*) assists the operations of the smaller one (*fl*[1]), and the lip, by abruptly bending itself at its point of attachment and laying its basal part across the food, presses it into the mouth, while the terminal portion is kept in a constant wavy vibration, and curved toward the posterior end of the body. This is usually done in three or four seconds, and then the cilia return to their usual positions, while the introcepted edible passes toward the centre of the body, and is there immediately enclosed in a digestive vacuole (fig. 51, *d*). For a while the food dances about in this vacuole with a very lively motion, but finally it subsides into quietude."

"*The contractile vesicle* (*cv*). — There is a two-fold difficulty in discovering the presence of this organ. In the first place it is comparatively quite small, and secondly, it pulsates so slowly that it is very rarely possible to see it contract twice in succession between any two of the abrupt, lateral deviations of the body, which the spasmodic twitchings of the arcuate flagellum produce. On this account it has not been possible to determine the precise rate of its systole and diastole. It seems to contract from three to four times a minute. It lies near the surface, about half way between the two ends of the body, and nearly midway between the two extremes of its greater diameter. At the completion of its *diastole* it has a circular outline, and appears like a clear, colorless vesicle in the midst of the yellowish tissue of the body. Upon contraction it disappears, and leaves no trace of its presence. The *systole* progresses slowly, as in *Anisonema* (*A. sulcatum*, Duj. ? and *A. nov. sp.* [*A. concavum*, § 13]), *Cyclidium* (*C. nov. sp.*), and *Phacus pleuronectes*, Duj.; and in this respect contrasts strongly with the same process in *Heteromita fusiformis*, Jas.-Clk., *Astasia tricophora*, Clap. (§ 12), and *Cryptomonas (C. nov. sp.)*, in which the last half of the systole is very abrupt and marked."

"*The stem.* — In addition to what has already been said of the general appearance of this part of the organism, it may be added that the older and basal portions (fig. 63) of the branches are flat, and have a distinct longitudinal, irregular striation; to all appearances made up of the older, laterally agglutinated twigs. The youngest, terminal portions (fig. 47, *pd*) of the branches which, under the name of twigs, have been described in this paper as the immediate supporters of the colonies of monads, are evidently tubular (fig. 62). They appear to be as flexible as a spider's thread, and are usually quite irregular in outline, and in the calibre of the canal which permeates them. The wall of these tubular twigs is quite thick, and is alike rough on the exterior and interior faces. The substance within the tubes appears homogeneous, but whether it is solid or fluid could not be determined. The oldest part of the stems is of a reddish-brown color, but as they taper off into branchlets they gradually assume a gamboge color, and finally terminate in scarcely colored twigs."

"*Reproduction* by fissigemmation (figs. 52–61), is the only method of propagating individuals which I have observed. As a preliminary to this process the monad gradually loses its fusiform shape, and assumes at first an oval contour, and finally becomes globular (fig. 52). During this transition both of the prehensile cilia (*fl*, fl^1) become much more conspicuous than usual, and the body develops a closely fitting hyaline envelope (*h*) about it; thus passing into a sort of encysted state. The contractile vesicle (*cv*), however, does not seem to cease its pulsations during this period, and moreover it becomes quite conspicuous. This arises mostly from the fact that the body is in a nearly quiet state, and allows the observer to obtain a prolonged and undisturbed view of it. Unfortunately the rate of the pulsations of this organ was not ascertained when the following observations were made, because the whole time was occupied in watching aud drawing the various and rapidly changing phases of self-division."

"After the body assumes a globular shape, as above mentioned, both the larger and smaller cilium seem to be undergoing a change, and become indistinct in outline. Presently two larger flagella (fig. 53, *fl*) burst upon the view, apparently by the longitudinal splitting of the previously single one of the same kind, and rapidly separate from each other by the broadening of the body, leaving between them the smaller cilium. The latter at this time appears much thicker than usual, and seems to be composed of two closely approximated, parallel threads (fl^1). By this time the contractile vesicle has also divided into two, which lie closely side by side."

"At this moment the time noted in one series of observations was 2.30 P.M. By 2.35 P.M. (fig. 54), the larger flagella (*fl*) had separated still farther, and the smaller cilium had split into two (fl^1) very conspicuous filaments; as yet, however, attached to a common point of the body. From this time forth to the completion of the process of fissigemmation, all of the cilia kept up a slow vibration, in which they undulated from base to tip with a sort of snake-like motion. By 2.45 P.M. (fig. 55), the body had become quite appreciably broader than long; the contractile vesicles (*cv*) were widely separated, and the smaller cilia had left between them a considerable space, and each one had approximated quite near to the base of a larger flagellum. At 2.50 P.M. (fig. 56), the body had become nearly twice as broad as long, and the space (c^1) between the two pairs of cilia was nearly twice as great as in the last phase, and considerably depressed in the middle, so that the body had a broadly cordate outline. By 2.52 P. M. (fig. 57), the posterior end of the body — at a point a little to one side of the spot where it was attached to the pedicel — was also slightly indented, so that in outline it presented a guitar-shaped figure, each rounded half of which bore a pair of unequal cilia, and contained a contractile vesicle. In one minute more the contraction had increased to such an extent that the body was divided about half way through (fig. 58). By 2.54 P. M. (fig. 59), the animal had a dumb-bell shape, and the pedicel (*pd*) was attached to one of the segments near the point of constriction. Still the process went on very rapidly, and by 2.55 P. M. (fig. 60), the new bodies were widely separated, but still attached to each other by a mere thread. At 3 P. M. (fig. 61), the body which was attached to the pedicel was left alone, and its companion swam away to seek a new attachment, and build up its stem."

"To the last moment the hyaline envelope remained about the segments, and in fact so long afterward that time and circumstances did not allow me to ascertain its final disposition. I would remark, however, that when the ovate bodies of the half-grown monads (fig. 49) are contracted temporarily into a globular shape, they appear identical — excepting that they lack the hyaline envelope — with these recently fissated forms. In all probability, therefore, the latter lose their envelope and assume the shape of the former."

"As to the development of the stem, I think it quite certain that it grows out from the posterior end of the body. The best proof of this is that I have frequently found a monad — especially in the condition of the one which I described above as breaking loose from its companion — nearly sessile upon a clean spot, and attached by a very short, faint, film-like thread. From this size upward I have no difficulty in finding abundant examples as gradually increasing in diameter as they did in length; thus furnishing a pretty strong evidence that the stem grows under the influence of its own innate powers, and is not therefore a deposit emanating from the body of the monad, except, perhaps, as far as it may be nourished by a fluid circulating within its hollow core."

§ 12. Astasia tricophora, Clap.

(Plate IX., figs. 45, 46).

The transition from the mononematous *Monas*, *Codosiga*, *Leucosolenia*, &c., to those heteronematous *Flagellata* which possess at the same time a proboscidiform and a gubernacliform *flagellum* is most aptly exemplified by that curious mimetic combination of *Amœba* and *Anisonema* known as *Astasia tricophora*, Clap. (*Trachelius tricophorus*, Ehr.). At first sight it appears to be capable of all the abrupt retrogressive motions and short turnings of an *Anisonema* (figs. 65–69), without being endowed with a similar means of locomotion. One is not long, however, in discovering the homologue of the *trail* (fl^2) or rudder (*gubernaclum*) of the latter in the posterior, abdominal, triangular prolongation (fig. 45, fl^2) of the body of the former. That this is the true interpretation of the prolongation, is warranted not only by the use to which it is put, as a sort of *point d'appui* during the amœboid retroversions of the body, but also by its persistent form whilst the animal is contorted into a shapeless, writhing mass. In the midst of the paucity of distinctive topography, we are also furnished by this organ, if I may so call it, with a basis of ready discrimination between the practically ventral and dorsal sides of the body; for, although it may not lie strictly in the central line of progress during reptation, — nor could we expect to find it there upon being referred to its homological relation to the asymmetrically attached *gubernaculum* of *Anisonema*, — it none the less belongs to the reptant side of the animal, and as it were, controls its motions, and acts as a keel upon which the posterior end of the body vibrates and reels from side to side. Finally, in reference to this point, it may be added, that this species does not swim, properly speaking, nor has it the character of the revolving natant forms, such as Dujardin separated from the *Astasia* of Ehrenberg, and described under the name of *Peranema*.

For the sake of accumulating and multiplying diagnostic characters, that shall serve us hereafter as discriminative points in determining the classificatory relations of *Flagellata*, it is most desirable that every critical study of one of these forms should be carefully recorded, even to the minutest details. On this account, therefore, and particularly in the present connection, notwithstanding that this species is so frequently met with, and apparently so well known, it will not be out of place here to describe it anew; especially as some of the features presented for the consideration of naturalists are not in accordance with the interpretation put upon them by previous observers.

The *body* of this animalcule is colorless, but frequently has a slight yellowish or reddish tinge, which is derived by diffusion from the granular contents of the interior. The only legitimate color present lies in the very faint red eye-spot (*s*). The form is variable from elongate ovate to cylindrical, with a gentle taper, at the anterior third, into a narrow, truncate-emarginate head. Posteriorly the dorsal region is rounded, but on the ventral face a broad, triangular prolongation (fl^2) — already spoken of as the homologue of the *gubernaculum* of the reptant *Heteronemata* — extends backward beyond the outline of the *dorsum*. The exact relation of this prolongation to the axis of the body is not to be determined beyond a doubt, because of the constantly shifting attitude of the animal; at one moment the *gubernaclum* (fl^2) is on the left, and then at the next instant it appears on the right of the mesial line, or follows for a while between these two points, according as the body keels over more or less from one side to the other, or balances itself in a median position. It appears most frequently, however, to be unilateral.

The amœboid contortions (fig. 46) of the body have already been mentioned, but I would add that this is only a resemblance, a mere suggestion, if one may use the term, of the mode of locomotion of *Amœba*; for it is not, as in the latter, an actual *flowing out* of a glairy mass into protean, reptant processes, but an exceedingly variable *puckering*, and always accompanied by a longitudinal contraction of the body; the one being evidently necessary to the other. If I may carry out the niceness of distinction further, I should say that whilst *Amœba* is contractile and plastic, *Astasia* is retractile and flexible.

The *flagellum* (*fl*) also, by its subterminal attachment to the head, carries out the typical plan of the reptant *Heteronemata*. It is based strictly on the ventral side of the front, descending from the latter with such an abrupt turn forward that it appears, without close observation, to be a mere tapering prolongation of this region. Yet it is neither related to the body in the latter sense, nor an extension of it from any point of view, but is as strictly an appendage as any form of vibratile cilia,[1] and alike as incapable of contraction. It is so

[1] As my views in regard to the relation of vibratile cilia to underlying cells may not be fully understood in this allusion, I would refer to my published opinion of this subject, in a note appended to some remarks upon *Actinophrys*, in the *Proceedings of the Boston Society of Natural History*, for September, 1863, p. 283, and republished in the *Annals and Magazine of Natural History*, for December, 1864.

stout and thick that one need not be surprised to find Ehrenberg, in the absence of a knowledge of the structure of this animalcule, mistaking the scarcely tapering *flagellum* for the frontal prolongation of a *Trachelius.* Usually it is about half again longer than the body, but that of very large animals often greatly exceeds this proportion. Its mode of action, as a propulsive organ, is not like that most frequently exhibited by the *flagella* of the truly natant *Flagellata,* for whilst in the latter case the vibrations pass along the whole length of the *cilium,* in the former they are confined to its distal end, and moreover they seem to be different in character; since instead of simply undulating in a more or less restricted plane, the *flagellum* twirls at the tip rather after the manner of a revolving helix.

This method of progression is singularly modified by a rhombic meniscoid species of *Cyclidium,* Duj. (non Ehr.), whose *flagellum* during reptation projects — from a deeply subterminal point of the convex side of the body — without flexure almost to its tip, and then simply bends with frequent and vigorous strokes in the form of a hook, which it applies sidewise against the surface over which the creature is passing, and drags it after it, tilted over on one of its flanks, in a hitching, sidelong manner.

As a tactile organ, and for the purposes of prehension, the *flagellum* appears, by its great flexibility and vigorous action, to be eminently capable. Feeling about it with all the apparent expectation of finally meeting with something, the animalcule keeps its proboscis in a constant quiver, lashing it backward and forward in the meanwhile, or thrusting it along its flanks and then abruptly withdrawing it, very much after the manner of a *Lachrymaria.* When a particle of food is brought near the mouth (*m*), it is, as it were, coaxed into it by the light pulsations of the *flagellum,* apparently assisted by the movements of the buccal margin.

The *eye-spot* (*s*), so-called, naturally comes under consideration in connection with the tactile organ. It is a very minute circular body, apparently about as broad as the diameter of the *flagellum,* which lies a short distance behind the end of the head and just in front of the mouth (*m*). Frequently, from its excessive faintness, and light red color, it appears to be absent. but under careful scrutiny it may always be detected. The tendency which prevails to undervalue the importance of this body because it is present in an apparently similar position in the zoöspores of *Algæ,* no doubt hinders our advancement in the knowledge of its true character and function. Whether it is an organ of vision of any grade, or even a sensorial centre of any kind, can only be brought within the range of probability. Its constant presence demands attention, and should excite inquiry on that ground alone; but when, moreover, we find it in a position which corresponds to that in which the chief sensorial centres are usually situated, no mere resemblance to something else should divert us into a train of fancies about the homologies of the red oil globules of the zoöspores of *Algæ,* whilst the main point at issue is left in obscurity.

If we cannot add any thing further that is positive in regard to this organ, it will be well at least to attract attention to it in relation to its homologue in other *Flagellata.* In *Phacus pleuronectes,* Duj., it is not a uniform red spot, but seems to be divided into two regions, one of which is lunate in shape and of a bright red color, and projects forward from the upper side of the other like an appendage; whilst the main part is more deeply seated in the dorsum, and consists of a colorless, but quite conspicuous, irregularly circular disc, about as broad as the contractile vesicle, which it partially overlies. In this case one might, with a fair show of reasonableness, suggest that the red portion alone is the true eye-spot, and that the colorless disc is a sensorial centre, not only for the former but also for the *flagellum*, which arises close to it, on the ventral side. When we recall instances of the presence of a similar disc, which is unaccompanied by a red spot, in certain species of uniflagellate, natant *Flagellata* (*Peranema?* Duj.), and mark how long it is persistent after the body has fallen to pieces for the lack of fresh water, one cannot but feel that its superior consistency is a fair warrant for the belief that it is at least an important organ, and that, seeing the very faint color of that of *Astasia trichophora*, the absence of all tint does not necessarily exclude it from the category of visual organs. On the other hand, it might be justly questioned whether even the deepest colored spots are at all sensitive to light; and the only answer would be, that analogy renders it highly probable that they are.

The *mouth* (*m*) is a very marked feature when contrasted with that of other *flagellifers*. It is usually to be observed in a closed state (fig. 46, *m*), when it may be recognized as a short, dark, sharply defined double line trending lengthwise with the body, and situated on the ventral side, a short distance behind the base of the *flagellum*, and just in front of the contractile vesicle. When open it has a more or less broad oblong shape, and is more conspicuous than when closed. During the introception of food it is quite active, but whether for the purpose of mastication, or merely to manœuvre the incoming particles, cannot be said positively, although it is probably with the latter design. The peculiar knobbed, particolored aspect of the body is due to the almost invariably present large, highly refracting, red and yellow granules in the general cavity.

The *contractile vesicle* (*cv*) is situated just behind the mouth, but near the dorsal side of the body. At full diastole it is globular, and its diameter is one third of the breadth of the region in which it is situated. The systole is abrupt, and appears to be complete; and the diastole is slow, seeming to occupy all of the intervening time between the systoles. The rate of systole was not ascertained with sufficient accuracy to be recorded, but I should judge it to be not more than four or five times a minute.

The *reproductive organ* (*n*) is probably represented by a very large, light, oval mass which nearly fills the middle of the body. It has a decided outline, and, with the exception of a rather large, central, nucleiform body, its contents are homogeneous.

§ 13. Anisonema (A. concavum, nov. sp.)

(Plate X., figs. 65–69.)

Among all the heteronematous gubernaclifers, *Anisonema* possesses the highest degree of differentiation in its flagella (fl, fl^2); for whilst in *Heteromita* and *Heteronema* these organs are comparatively more like each other, and arise from a nearly common point, as in the *Homoionemata*, in the former genus they exhibit a greater diversity of character, and also originate from more widely separated regions. These are particularly observable in the species before us now, and are certainly more valuable diagnostic characters than the presence of an uncontractile integument by which to distinguish it from its congeners. The habitat of this animalcule is among tangled masses of confervoid *Algæ* in ponds and ditches, where decaying substances are most abundant. Upon these it moves with a more or less uneven pace; at one time gliding over a smooth surface with scarcely a perceptible effort, and at another progressing with a laborious, hitching gait, and lashing its *gubernaculum* (fl^2) about, and swinging its body from side to side, with frequent jerks, in its effort to pass over some obstacle.

The *body* is colorless, and enclosed in an uncontractile, smooth integument. It has an asymmetrically ovate shape, rounded behind, and rapidly narrowed anteriorly into an oblique, truncate conical front. Dorsally it is convex (figs. 67, 68), but ventrally, *i. e.*, on the reptant side, it is concave on the right and in the middle, and so strongly incurved on the left, that its sharp edge (t) reaches nearly to the median line. Beneath this inrolled border the enclosed space (fig. 68, t^1) projects into the left side like a longitudinal, covered way. In front it is very deep, but from that point going backward it narrows gradually, and finally, with the inrolled edge, fades out at the posterior third of the body.

The *two flagella* ($fl\ fl^2$) are as widely diverse in character and function as any two similar organs in the whole group of *Protozoa*. The anterior one (fl) is, strictly speaking, the prehensile organ, as well as the main propulsory agent. It is quite delicate, and tapers gradually, from its subterminal base within the longitudinal covered way, to an extremely fine tip. In point of length it varies from one half to two thirds longer than the body. It is always carried in an extended position in front, and vibrates very actively, especially during reptation.

The posterior flagellar organ, or *gubernaclum* (fl^2), is from three to four times the length of the body, and arises far from the front, in the deepest part of the covered way (fig. 68, t^1), and immediately beneath the contractile vesicle (cv). It is therefore attached quite near to the left margin of the body, and between the anterior and middle thirds. Its base, which is applied very obliquely to its point of attachment, is quite broad, but it narrows rapidly into a uniformly, but scarcely tapering lash, which always projects forward more or less, and then curves backward and extends to a long distance behind. During reptation over smooth surfaces it lies along the abdominal, median line, and trails behind in long gentle undulations. Although it never vibrates, it frequently lashes about, and applies itself against obstacles on the right and left, or even in front, and acts as a prop upon which the body is thrown from one side or the other, according to varying circumstances. That it is contractile would seem incontestible upon observing the sudden jerk with which it sometimes draws the body back toward its distal end; but I am pretty well convinced, from a careful study of this movement, that, although this organ may be to a slight degree *resilient*, it is not truly contractile, but rather *flexible*, and exhibits its muscular power by bending itself into coils or zigzags. Occasionally specimens are met with which have an additional pair of flagella (fig. 69, fl^3), of a more delicate kind, attached near the others. That these originate as a preliminary step to fissigemmation, although that phenomenon was not witnessed in this case, there can be scarcely a doubt, inasmuch as it accords perfectly with what has been observed in *Anthophysa* (p. 329).

The *mouth* has not been demonstrated to a certainty, by actually seeing food pass into it, but an approximative determination was reached by observing particles of matter, which were brought down by the prehensile *flagellum* (fl), pass into the body somewhere near the front, and apparently within the compass of the covered way.

The *anus* (figs. 65, 66, a) was adjudged to be at the posterior end of the animal, by noticing, in a couple of instances only, a clear, more or less irregular, rounded mass in this region, and its final disappearance while under observation; but the substance was so transparent that it was not possible to decide positively whether it made its exit upon the dorsal or the ventral side.

The *contractile vesicle* (*cv*) is a comparatively large organ, with a rounded contour when in full diastole, and quite faint and inconspicuous. It lies above the base of the *gubernaclum* (*fl*^{2}), the expanded base of the latter appearing at times to form a part of it, and by its movements — causing an alternation in light and shade — tends to mislead one into the belief that the systole is very irregular. A careful adjustment of the lens, however, reveals the true pulsation, and shows that the systole has a very slow rate.

§ 14. Heteromastix, Jas.–Clk.[1] (H. proteiformis, Jas.–Clk.)

(Plate X., figs. 70, 71, 72, 73, 74.)

I shall not describe this infusorian in the same systematic manner that has been adopted in treating of previous genera, because I do not know much about its internal organization; but in order that the direct alliance of the *Flagellata* with the *Ciliata* may be illustrated in this memoir in its strongest light, and inasmuch as *Heteromastix* is by far the best example of such a transition between the two above-mentioned orders, I shall take the liberty of quoting what I have already published in regard to it in another place.[2]

"Here is an infusorian (figs. 70–74), from fresh water, which, although it has a pretty strong resemblance to *Euglena*, heightened by the presence of a red eye-spot (*s*), will be found, upon investigation, to possess some additional and decidedly different characters. In the first place, it has two vibrating lashes (*fl fl*^{2}), which differ remarkably among themselves both in position and character. One of them is always carried in front like a sort of proboscis (*fl*), and in fact, it seems to have the office of such an organ, like that of an elephant, to feel and to take hold of objects. I must confess that I was struck with astonishment at the apparent intelligence with which the infusorian extended and twisted and turned and felt about with this extraordinary organ. Never did an elephant seem to use his trunk with more thoughtfulness. With like control did the animal also use the other lash (*fl*^{2}), always keeping it turned back along the body; so that it formed a kind of movable keel, when the little creature glided along in its watery element, or was used to sway it from side to side, or oftentimes to raise it up on its tail by forming a prop, as we see it in this other figure (fig. 73.)

"The motory or propelling power, on the other hand, is restricted, at least in the greatest measure, to another kind of vibratile cilia. These are very short, and are crowded together in great numbers (*cl*) in a broad furrow or depression (*f*), which extends over half the length of the body, along its inferior, middle line. When the body is turned over, and the anterior end retracted and swelled out sideways, the furrow (fig. 73, *f*) becomes quite conspicuous, and the extent of the group of minor cilia (*cl*) is easily ascertained. They are very minute and in constant motion, propelling the body backward and forward, up and down, to the right or left, according as it is steered by the trailing lash (*fl*^{2}) which extends along its length. Thus it is, that, although similar in form, a diversity of functions is laid upon these three kinds of cilia that amounts to the most marked specialization, through the simplest means; in fact, so simple that the eye cannot detect them in any form beside that of pro-

[1] ἕτερος, dissimilar. μάστιξ, a lash. This genus was originally described in my published volume of Lowell Lectures. *Mind in Nature*, p. 146, fig. 88.

[2] See note 1.

portion and position, and certainly not in the intimate structure of these bodies. The whole body, too, possesses a flexibility and extensibility scarcely inferior to its cilia; at one moment it is darting through the water, sharp as a lance at both ends, and at the next it is as round as a ball, or worming its way through tortuous passages with every possible degree of flexure short of actually tying itself into a knot."

It would be difficult to say now whether *Heteromastix* belongs to the *Flagellata* rather than to the *Ciliata*, or *vice versa*. The structure, position, and peculiar mode of action of its flagella recall *Anisonema* (§ 13) most vividly to mind, but, on the other hand, the group of cilia (*cl*) in the obliquely longitudinal furrow (*f*), in close proximity to, and evidently acting more or less as allies with the flagella (*fl*, fl^2), find their parallel in the "proboscis-like lash" (fig. 75, *fl*), and vestibular cilia (*cl*) in the oblique buccal furrow of *Pleuronema* (§ 16), and *Dysteria* (§ 15). How closely allied the two latter are to the former is not the immediate question here; it is, are they related at all? We think there can be no hesitation in replying in the affirmative; but in order that the reader may have the proof before his eyes, I think it will not be out of place, in this memoir, to introduce some of the undoubted *Ciliata* which possess at the same time organs that are as truly flagellate in character as are the flagella of *Anisonema, Astasia*, etc., etc. The genus *Dysteria* shall be our first example.

§ 15. Dysteria, Huxley. (D. proræfrons, Jas.–Clk.[1])

(Plate X., figs. 77, 78.)

This species "is an infusorian between two leaves or flexible shells (v, v^1), of unequal width, which are united by a sort of hinge along the left border and gaping to a more than equal extent along the right side, where the upper one (v) far overhangs the other (v^1, *bk*) throughout the whole length of its free edge. The broader or dorsal shell (v) is convex toward the eye, and the whole organization lies within its concavity, whilst the narrower one (*bk*, v^1) is flat, simply covering the body, and as a natural consequence does not include any part of it. The open space between them is endowed with a row of closely-set, large, vibratile cilia (*cl*), which differ in size according to their position; those in front being by far the longest, and those along the side scarcely more than half as long; and in addition there is one (*fl*) which, from its great size, has more of the character of a proboscis, or prehensory flagellum, and is attached nearly at the extreme anterior border of the row" (*cl*).

"It is not an easy matter in this case to determine how much of the one-sided, cilia-bordered furrow corresponds to the disc or vestibule of *Epistylis, Stentor, Paramecium*, or *Pleuronema*; nor does it affect the question of the degree of obliquity of the conformation of this animal, so long as we see that, whatever it may be, either wholly or in part a vestibule, it is at least extremely oblique, and that it is not possible to view it from any point but that the body appears asymmetrical in relation to it."

"The most striking peculiarity of this creature is its habit of swinging around on a pivot (fl^2), which consists of an ovate or lancet-shaped appendage, of considerable dimensions, that projects from near the posterior end of the body, and in the line of the row of cilia. The pivot possesses perfect flexibility at its base, so that the animal can move over a considerable distance backward and forward without disturbing the point. Most of the time it keeps the flat side down when gyrating around its place of attachment; but now and then

[1] See *Mind in Nature*, ut sup. p. 171, fig. 100.

it turns upon its right edge, and performs its eccentric rotations about the appendage. This is the habit which, as I said before, has impressed some observers with its similarity to the Rotifera. In connection with this, too, it happens that the creature possesses a pair of jaw-like, or rather pincer-like bodies (m^1) which lie near the entrance to the mouth, and occasionally open and shut like a pair of forceps, just as similar bodies known as the jaws of Rotifers do, whilst food is passing between them. Excepting the passage between these jaws, there is not the least trace of an intestine, nor of any definite cavity devoted to digestion. The food occupies the whole length and breadth of the body, under the same circumstances as are observable in *Parameeium*, *Pleuronema*, *Stentor*, etc.

"The contractile vesicles are two (*cv*, *cv*) quite small globular bodies, one of which is situated just to the right of the jaws (m^1) and the other close to the base of the pivot (fl^2); and although they contract very slowly, not oftener than once in four or five minutes, they evince every characteristic, in action and physiognomy, of true infusorian, pulsating vesicles. The large colorless reproductive organ (*n*) singularly exemplifies in itself the one-sidedness of the animal by its conformation to the shape of the body. One side of it is convex, and, like the rest of the organization, projects into the concavity of the larger shell, whilst the other face is flat and, as it were, moulded upon the plane shell. It forms a very conspicuous object just to the left of the jaws, and might easily be mistaken at first glance for a contractile vesicle, especially as the true representatives of that organ are so very inconspicuous both in regard to their size and actions.

"Now in all the organization of this animal there is nothing which is not strictly infusorian in character. The jaw-like bodies (m^1) are not confined to this alone, for there are quite a number of others which possess a similar apparatus at or near the mouth. Chilodon has a complete circle of straight rods around the mouth. As for the pivot (fl^2), it is nothing but a kind of stem, such as exists on a larger scale in *Stentor*, or is more peculiarly specialized in the pedestals of *Epistylis*, *Zoothamnium*, or *Podophrya;* and, as counter to what we see in these last, I would state that there are certain of the Vorticellians, closely related to *Epistylis*, which have no stem whatever, and swim about as freely as *Dysteria*."

§ 16. Pleuronema, Duj. (P. instabilis,[1] Jas.–Clk.)

(Plate X., figs. 75, 76.)

This infusorian bears such a strong resemblance to *Heteromastix* (§ 14) in some of its external features, that it seems as if it might more properly have succeeded the latter in the illustration of my subject; but mere resemblances do not always indicate relationship, and in the case of *Pleuronema*, in particular, this is most true, for it is decidedly a far more highly organized animalcule than *Dysteria*, as we shall see by what I shall now quote from an already published description.[2]

"What I wish now to show in the *Pleuronema* is the triple, or I might say even the quadruple diversity of the vibrating cilia, or in other words, a quadruple specialization of one type of organs, by their manifold offices ranking their possessors above those of their class which attain to a less degree of complicity in this respect. The most prominent of these cilia are those which are arranged in longitudinal rows (fig. 75, cl^1) over nearly the whole extent of the body, and which most frequently are seen in a quiet state, projecting far out

[1] See *Mind in Nature*, ut sup. p. 148, fig. 90. [2] See note 1.

from the surface like so many fine, rigid bristles. In fact, the motions of this animal are so lightning-like in rapidity that I have never seen this form of cilia except when the body was in a quiet state; and therefore I judge that, as they do not move then, they are the principal organs of locomotion. There is on the right side a group of much more heavily built cilia (*cl*), which project from the oblique furrow in which the mouth (*m*) is set. They are more particularly devoted to producing currents in which the particles of food may be brought to the mouth.

"We see, also, projecting from the forward end of the oblique furrow, and near the anterior edge of the mouth (*m*), one of those proboscis-like lashes (*fl*) [a *flagellum*] which are so characteristic of the lower, ciliate [flagellate] infusoria; but yet it would not seem to have the same office as in the latter, since it is usually held in this position, apparently as rigid as if it were a wire; and only now and then does it move, by a sudden jerk, and disappears in the oblique furrow; probably acting there in concert with the other cilia in the introduction of food into the mouth. The fourth and last kind of cilia of which I have to speak, consists of two excessively faint, very long, and quite large, bristle-like filaments (sl, sl^1), which project from each end of the body. The straight one (*sl*) always precedes when the creature is in motion, and the curved one (sl^1) is attached a little to the left of the posterior end of the body. Both are always rigid when the animal is not in motion, — but yet there can be no doubt that they are flexible, for at times they disappear suddenly, and probably are bent under the body. What their office is I cannot say, but conjecture, from their resemblance to what are called the saltatory bristles of other infusorians, that they are used as accessory means of sudden propulsion, or leaping, — a habit which seems to be the most frequent mode of leaving any point at which the creature has fairly come to a stand-still.

"The contractile vesicle (*cv*) lies close to the forward end of the body, and corresponds in activity to the vivacity of the motions of the latter. It contracts every ten seconds, and with more vigor than any other that I know of. It is very conspicuous, as it is two thirds of the time in an expanded state; and disappears and reappears like the sudden closing and opening of a large eye.

"I have already indicated the position of the mouth (*m*) as being near the broader, anterior end of the oblique furrow, but again speak of it here in order to make the description of the digestive system complete. From the mouth (*m*) the food passes directly into the general cavity without going through any throat, and most frequently combines in large masses (*d*).

"The presence of a reproductive organ (*n*), which we find here in the form of a clear, colorless, globular body, when added to all the other systems which I have mentioned, puts this animal in the condition of a fully organized, ciliated infusorian; and would seem to give us full warrant for believing it to be the culmination of a progressive development, whose tendency is to pass through such forms of animate organization as we have just been tracing in the successively more and more complicated creatures whose images are before us."

Description of the Figures of Plates IX. and X.

The corresponding parts in the figures are lettered alike, excepting when otherwise stated in the description ot any particular illustration.

a. anus. — *b*, membranous collar; b^1, edge of *b*; b^2, base of *b*. — *bk*, the beaks of the valve of *Dysteria*. — *c*, calyx; c^1, aperture of *c*; c^2, lower half of *c*. — *cl*, cl^1, vibratile cilia. — *cv*, contractile vesicle. — *d*, digestive vacuole, or ingested food. — *e*, furrow in fissigemmation; e^1, anterior end of *e*; e^2, prolongation of *e*, e^1. — *f*, broad sulcus, (in *Heteromastix*). — *fl*, flagellum; fl^1, minor flagellum; fl^2, *gubernaclum*. — *fr*, frontal area. — *i*, neck, or anterior half of body. — *lp*, lip. — *m*, mouth; m^1, jaws. — *md*, monads of the Sponge, etc. — *n*, reproductive organ. — *o*, ostioles. — *pd*, pedicel; pd^1, top of *pd*; pd^2, forks of *pd*. — *r*, retractor muscle; r^1, furrow in which *r* is imbedded, and attached. — *s*, eye-spot. — *sl*, sl^1, saltatory cilia. — *sp*, triradiate spicula, sp^1, aciculate spicula. — *t*, margin of the inrolled side of *Anisonema*; t^1, the deep furrow or covered way behind *t*. — *v*, broader valve of *Dysteria*; v^1, the narrower valve.

Explanation of Plate IX.

Figs. 1–4. *Monas termo*, Ehr.? Fig. 1, a group of free monads. 500 diam. Fig. 2, a free monad seen from the narrower side, with the lip (*lp*) next the observer, and the contractile vesicle (*cv*) in profile. 950 diam. Fig. 3, an attached form seen from the broad side. 1200 diam. Fig. 4, a free monad in the act of swallowing a large morsel of food. 950 diam.

Figs. 5, 5^a, 5^b, 6. *Monas neglecta*, n. sp. Fig. 5, broad-side view of a pedicellated monad. 950 diam. Fig. 5^a, a posterior view showing the axial attachment of the pedicel (pd^1) and the contractile vesicle (*cv*) in profile, and the flagellum (*fl*) in the distance. 950 diam. Fig. 5^b, a free monad in the act of swimming. 950 diam. Fig. 6, an attached form, contorted in the act of swallowing a large morsel of food. 950 diam.

Figs. 7–27. *Codosiga pulcherrimus*, n. sp. Fig. 7, a colony of eight monads, drawn within an hour after the fissigemmation of three of its members. 150 diam. Fig. 8, a group of five, in a bird's-eye view. 500 diam. Fig. 9, a single monad, with three contractile vesicles (*cv*). The dotted lines indicate the degree of the lateral vibrative expansion of the membranous collar (*b*). 950 diam. Fig. 10, the same as fig. 9, preparing to undergo fissigemmation; the body is contracted and widened, and the collar (*b*) broadened. Figs. 11–22, to illustrate the process of *fissigemmation.* 750 diam. For particulars see the text (p. 316). Fig. 23, a free monad in the act of swimming; the vibrating flagellum (*fl*) acting as a propulsory agent, and following in the rear. 950 diam. Fig. 24, a single, pedicellated monad from old, stale water; the membranous collar (*b*) contracted into a cone, and the flagellum (*fl*) vibrating rapidly. 950 diam. Fig. 24^a, a very large pedicellated form, just before *fissigemmation* begins; the body partially contracted, and the collar (*b*) vibrating. The peculiar sigmoid curve of the flagellum (*fl*) is well shown here. 950 diam. Figs. 25, 26, 27, showing the different degrees of contraction of the membranous collar (*b*) of the same individual. In fig. 25, the *flagellum* (*fl*) is vibrating rapidly, just at the moment when the collar (*b*) has returned to its usual form and attitude. 750 diam.

Figs. 28–32^a. *Salpingœca marinus*, n. sp. Figs. 28, 29, 30, the same individual in different states of expansion. 1900 diam. Fig. 31, the body completely filling the calyx, so that the latter is scarcely distinguishable, except at its mouth (c^1). 1900 diam. Fig. 32, showing the calyx as a distinct envelope considerably separated from the body at the bottom (*c*) and at the aperture (c^1). 1900 diam. Fig. 32^a, an empty calyx closed. 1900 diam.

Figs. 33, 33^a, 33^b, 33^c. *Bicosœca lacustris*, n. sp. Fig. 33, an adult, with the lip (*lp*) nearest the eye, the flagellum (*fl*) in the background, and the longitudinal furrow seen through the body. The flagellum (*fl*) is uncoiling just as the body emerges from the bottom of the calyx (*c*). 950 diam. Fig. 33^a, a young animal in profile, showing the peculiar attitude and curve of the flagellum (*fl*), the narrow aperture (c^1) of the calyx (*c*), and the unilateral attachment of the retractor muscle (*r*). The pedicel (*pd*) is just beginning to develop. 950 diam. Fig. 33^b, a young form partially emerged from the bottom of the calyx (*c*), the latter contracted at the mouth (c^1) and the flagellum (*fl*) forcing its way through, as is usual, in a loop. 950 diam. Fig. 33^c, the same as fig. 33^a, retracted to the bottom of the calyx (*c*) and the aperture (c^1) of the latter nearly closed. 950 diam.

Figs. 34, 35. *Bicosœca gracilipes*, n. sp. Fig. 34, the longitudinal furrow (r^1) and the flagellum (*fl*) next the eye; the lip (*lp*) in the background. 1900 diam. Fig. 35, the body retracted to the bottom of the calyx (*c*), and the flagellum beginning to uncoil. 950 diam.

Fig. 36. *Codonœca costata*, n. sp. The body seated in the bottom of the pedicellated calyx (*c*). 950 diam.

Figs. 37, 37^a, 37^b, 37^c, 37^d. *Salpingœca amphoridium*, n. sp. All magnified 950 diameters. Fig. 37, an individual suspended freely in its calyx (*c*, c^1). The dotted lines indicate the attitude which the collar (*b*) assumed for a while during the observation upon this specimen. A particle of fœcal matter has just left the anus (*a*). Fig. 37^a, the lower part of the calyx filled by the body, the upper part (c^1) free from the neck (*i*) of the animal, and the membranous collar unusually narrowed. Fig. 37^b, the calyx mostly filled by the body, the head (*i*) bent to one side, and the flagellum (*fl*) in the act of expelling a particle of undesirable matter. Fig. 37^c, an empty calyx, slightly contracted in dimensions. Fig. 37^d, the body contracted and filling the calyx, and the membranous collar (*b*) partially retracted.

Figs. 38, 39. *Salpingœca gracilis*, n. sp. 950 diam. Fig. 38, the body retracted within the calyx (c, c^1). Fig. 39, the same as fig. 38, partially protruded from the calyx.

Figs. 40–44. *Leucosolenia* (*Grantia*) *botryoides*, Bowrbk. Fig. 40, a colony of sponge; natural size. Fig. 41, view of a profile section of the monadigerous layer; the monads (*md*) closely packed together, side by side, with the membranous collar (*b*) and the flagellum (*fl*) projecting into the general cavity of the colony. 950 diam. Figs 42, 43, 44, isolated monads with the membranous collar (*b*) in various attitudes. 950 diam. See also fig. 64.

Figs. 45, 46. *Astasia tricophora*, Clap. Fig. 45, a dorsal view, the mouth seen through the head, and the *guber naclum* (fl^2) in the background. 500 diam. Fig. 46, the body in an amœboid, contorted state. 500 diam.

Explanation of Plate X.

Figs. 47–63. *Anthophysa Mülleri*, Bory. Fig. 47, a colony of adults attached to a single tubular branchlet or pedicel (*pd*). One of the monads is in the act of passing a morsel into its mouth (*m*). 950 diam. Fig. 48, a pair of adults, seen in profile. 950 diam. Fig. 49, a pair of young monads; one in profile and the other presenting its narrow side. 950 diam. Figs. 50 and 51, different attitudes of the same monad as the one in profile in fig. 49, during the introception of food. 950 diam. Figs. 52–61, to illustrate the process of fissigemmation. 950 diam. Fig. 62, a piece of a tubular branchlet like fig. 47, (*pd*). 1900 diam. Fig. 63, a piece of a flat branch from an old part of the colony. 950 diam.

Fig. 64. *Leucosolenia botryoides*, Bowrbk. A portion of the monadigerous layer (*md*) seen through the spiculiferous stratum, with the spicula next the eye. 500 diam.

Figs. 65–69. *Anisonema concava*, n. sp. All magnified 500 diameters. Fig. 65, a dorsal view, the inrolled margin (*t*) seen through the body. Fig. 66, a ventral view of fig. 65, the base of the gubernaclum (fl^2) covered by the inrolled edge (*t*). Fig. 67, a profile view of the right side of the body, showing its concavo-convex character. Fig. 68, an end view, to show the lateral extent of the covered way from which the *gubernaclum* (fl^2) and the anterior flagellum (*fl*) spring. Fig. 69, a ventral view of an animal which possesses two extra flagella (fl^3). It is probably in the incipient stage of fissigemmation.

Figs. 70–74. *Heteromastix proteiformis*, Jas.–Clk. All the figures are magnified 500 diameters. Fig. 70, profile view of the right side of a fully extended animal, the gubernaclum (fl^2) trailing beneath. Fig. 71, the same as fig. 70, in a partially contracted state. Fig. 72, an individual seen directly from below, with its anterior end strongly retracted and broadened. Fig. 73, an animal partially contracted and propped up on its tail by its flagella (*fl*, fl^2), and exposing its ventral, ciliated furrow (*f*) to full view. Fig. 74, an end view of the head, with the group of cilia (*cl*) on the lower side.

Figs. 75, 76. *Pleuronema instabilis*, Jas.–Clk. Fig. 75, a dorsal (ventral, homologically speaking,) view. 1000 diam. Fig. 76, an end view of the head; the contractile vesicle (*cv*) in the foreground, and the flagellum (*fl*) in the distance. A part of the ventral side is destitute of cilia. 500 diam.

Figs. 77, 78. *Dysteria proræfrons*, Jas.–Clk. Fig. 77, a view of the dorsal (homologically the ventral,) side, the broader valve (*v*) next the eye, and the narrower, three-beaked valve (v^1, *bk*) in the extreme distance. 600 diam. Fig. 78, a fore-shortened view of the body as it appears when turned up on its right edge; the head next the observer, and the pivot (fl^2) in the distance. 600 diam.

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X. *Notes on the Volcanic Phenomena of the Hawaiian Islands, with a description of the modern Eruptions.* *By* William T. Brigham, A. M.

Read June 20th, 1866.

As the study of the volcanic phenomena of the Hawaiian Islands requires a survey of the whole group, a physiographic sketch of all the Islands, even of those on which volcanoes have been long extinct, forms a part of the plan of this essay.

The Hawaiians reckon twelve islands: four large and four small ones inhabited, and four which are little more than barren rocks. They are named as follows: —

Nihòa,[1] . .	Barren Rock.		
Niihau, . . .	20 miles long,	5 miles wide,	elevation of highest point 1800 feet.
Kaùla, . .	Barren Rock.	Tufa cone.	
Lehùa, . . .	" "	" "	
Kauaì, . .	30 miles long,	28 miles wide,	" " " " 8000 "
Oáhu, . . .	35 " "	21 " "	" " " " 4000 "
Molokaì, . .	35 " "	7 " "	" " " " 3000 "
Lanai, . .	20 " "	9 " "	" " " " 2000 "
Máui, . .	54 " "	25 " "	" " " " 10,200 "
Kahooláwe, . .	12 " "	5 " "	" " " " 600 "
Molokìni, . .	Barren Rock.	Tufa cone.	" " " " 200 "
Hawaii, . .	100 miles long,	90 miles wide,	" " " " 13,950 "

The smallest, Kahooláwe, has an area of about fifty square miles, and the largest, Hawaii, of about three thousand eight hundred. The group extends in a north-north-west direction from this last island, and has nearly the average trend of the Pacific groups.[2] The Islands are all high, increasing in height and size, towards the south-east, where they culminate in the lofty domes of Hawaii. The rock of the whole group is volcanic, with the exception of the ancient elevated coral-reef and the resulting sandstone. No true fossiliferous rocks are found; although the tufa cones often contain fossilized shells, and corals of recent species. It has been the general impression that the lavas were wholly basaltic, but on the tops and in the interior of the mountains a variety of trachyte is found, and the bulk of the mountains seems to be composed of phonolites and graystones, forming a complete series from basalt to trachyte. These lavas contain few mineral species, but assume forms of great variety, and while tolerably uniform in composition, present structural differences in great number.

Occupying a central position in the Pacific these Islands have been visited, since their discovery by the Spaniards, by many government exploring expeditions, whose published accounts have intimated the interesting nature of the volcanic developments constantly taking place; but, except by the United States Exploring Expedition, no attempt has been made to examine carefully the geology. The Rev. Titus Coan, who has been for thirty years a missionary at Hìlo on Hawaii, has constantly observed every outburst of the volcanic fires during this period, and to his accounts we are principally indebted for what is known of their history on these Islands. Professor James D. Dana, also in his "Geology

[1] For the pronunciation and signification of the native names see Appendix.

[2] The principal groups in the Eastern Pacific have the following trends: —

Hawaiian Range, ...	N. 64° W.
Marquesas Islands, ...	N. 60° W.
Hervey Group, ...	N. 65° W.
Samoan Islands, ...	N. 64° W.

of the United States Exploring Expedition," and in subsequent memoirs, has done much to explain and extend our knowledge of the Hawaiian volcanoes. The information from these two sources is scattered through many volumes, and it has seemed desirable to collect and compare with the writer's own observations made during a residence of eighteen months, all hitherto published on the Geology of the Hawaiian Group.

KAUAÌ.[1]

[See Map, Plate XI.]

General Features. — Kauaì is from twenty-eight to thirty miles in diameter, nearly circular in form, and has an area of six hundred and forty square miles. As will be seen, it forms with Niihau, Lehùa, and Kaúla, a group closely connected in structure, as well as position. As on the other Hawaiian Islands, two centres of formation may be noticed, and the mountain summits are said to be thickly dotted with craters. Waíaleale, the highest peak, is situated a little east of the centre of the Island, and is supposed to be eight thousand feet high. West of this is a high table-land more than four thousand feet above the sea, which. extending over forty square miles, terminates in a precipice two thousand feet high. Waíaleale is much furrowed by deep valleys, the intervening ridges being sharp and irregular; the lava of which the whole Island is composed is much decomposed on the surface, and where not covered by the profuse vegetation of the tropics exhibits strata with a gradual dip of from 5°–10° towards the sea on every side.

On the coast of the north-eastern to the south-eastern part of the Island is a ridge, interrupted in many places, and of no great height, but seemingly detached from the great central mountain, being placed tangentially to the main ridges. The shore on the western side is precipitous, but elsewhere it is a sand beach interrupted by basaltic cliffs from ten to a hundred and fifty feet in height. The valleys are long, widening towards the sea and very fertile, the soil being sometimes ten feet deep. The rivers on the windward side of the Island are numerous, although not large, and as most of the low land lies on that side, Kauaì possesses a larger proportion of arable land than any of the other Islands. The south-west, or leeward district, is dry and barren, although several rivers descend from the mountains above.

It is more difficult to trace the original plan of Kauaì than of any of the other Islands, as its mountain summits are difficult of access, its valleys and ridges larger and more irregular, the lavas more decomposed, and the natural sections more concealed beneath the vegetation than on any other Island of the Hawaiian group. From the degradation of its ridges, and the absence of any very recent volcanic products, it has been supposed to be the oldest member of the group, and it cannot be disputed that volcanic action ceased here before it became extinct on Oáhu or the other Islands. Many years must have elapsed, — how many it is useless to conjecture, — to convert the hard basaltic lava into the rich soil which nourishes trees of immense size; and which is so abundant as to give Kauaì the name of The Garden.

[1] The most northerly island of the group, Nihòa or Bird Island, has never been visited by scientific men, but from the description of natives and others who have landed to collect the eggs which the birds deposit there in large quantities, it would seem to be the remains of an ancient crater, as it exhibits tufaceous and basaltic formations.

The rock of which the mountain is built, is a heavy compact ferruginous basalt, tolerably uniform throughout; while the shore ridges contain less iron, are more cellular, and vary in their structure from a compact phonolite to a heavy basalt. Crystals of quartz and iron pyrites are found in various parts of the Island, and in some places the silica of the lava has been converted into an opal-like irregular mass.

The valley of Hanaleì opens on the northern coast, and at its mouth is one of the best harbors in Kauaì. At the shore the valley is two or three miles wide, but its bounding ridges gradually approach each other, and five miles from the sea a narrow gorge alone remains, the bed of the largest river on the Island, of the same name as the valley. This river takes its rise in the swampy summit of Waíaleale and descends gradually without high falls. The last four miles of its course it has but little current, is from fifty to two hundred feet wide, and from two to fifteen feet deep. The bottom is gravelly or sandy, and free from stones. The plain bordering its banks is very fertile, and has been occupied in succession by plantations of mulberries, coffee, and sugar-cane.

Westward of the valley of Hanaleì there is a region about twelve square miles in extent, quite mountainous and much cut up by deep ravines. The valley of Waiòli is remarkable for its circular form and precipitous walls formed by the ridges Namalahóa and Namalokáma, between two thousand five hundred and three thousand feet high. Extending to the westward Namalahóa ends abruptly at the sea in a *pali* (precipice) about two hundred feet high. The cañons of Lumahaì and Wainìha are narrow and picturesque, with nearly perpendicular sides and frequent cascades. Every ravine is a watercourse, and after the frequent rains the white threads of the waterfalls are seen breaking out all over the palis among the bright green of the Kukùi (*Aleurites moluccana*) and the darker ferns.

The soil of the ridges near the shore is reddened by the oxidation of the iron which forms an important part of the Hawaiian lava,[1] and contains small boulders formed of concentric layers of a loose friable stone around a hard, amorphous, argillaceous core. These coats are loose and may be easily separated like the skins of an onion. The strata nearer the mountains where the rivers have exposed sections, are deep, (thirty to eighty feet,) and have a regular dip of 5°–10° towards the north. The exposed edges are much decomposed, the lava being generally cellular but not scoriaceous, and the soil formed is of a very dark color from the combination of the oxide of iron with organic acids, while the entire wall is often covered with the luxuriant foliage of the ferns, leguminous creepers, and Lobeliaceæ.

In the valley of Wainìha, some five miles from the coast, is the precipitous ascent to the high table-land of the western district of Napàli. This valley is exceedingly fertile, and is filled with the kukùi-tree, bread-fruit, orange, banana, the fragrant pandanus, and kalo (*Coloeasia antiquorum, var. esculenta*). The ford of the Wainìha River is difficult at high tide owing to the large and small loose, smooth stones on the bottom; the beds of the other rivers here are usually smooth and sandy.

Two miles beyond on the coast are the remarkable caves of Haéna formed in the abrupt broken end of the ridges of Mauna Hina. The largest cave is more than a hundred feet wide at the mouth and twenty feet high, extending into the mountain several hundred feet, gradually becoming narrower and lower, until the explorer is obliged to creep on hands and knees to an artificial wall which is said to block up a sepulchral cave. The roof is very

[1] See Analyses below.

rough, and water drips through in many places. The floor is tolerably even and level and covered thinly with a black mould. This seems to have been one of those gigantic bubbles common in all lava streams; but half a mile beyond are two caves of less simple form, both occurring in the solid compact lava a few rods apart and half a mile west of the first cave. The more westerly one contains a pool of fine cool water, perfectly fresh, although on a level with the sea and but a few hundred feet from the shore. As the water extends the whole width of the cave, about one hundred feet, it is not easily accessible, but at a short distance from the entrance, which is fifty feet perhaps in height, the walls contract until only a low arch is left, hardly high enough to admit the passage of a canoe. The water is said to be forty feet deep, natives diving and bringing up stones from that depth. The other cave between the two former is much more remarkable; the water which fills it is of a most remarkable clearness. A scum of some insoluble white substance, of such tenuity as to render futile all attempts to collect it for analysis, usually covers the surface when the wind does not blow into the mouth of the cave. A few yards from the shore, where the water was thirty feet deep, the smallest pebbles could be seen with great distinctness. The shore-line of this reservoir was one hundred and eighty feet long. The entrance was formed by a low arch traversed by a narrow dyke, and seemed to have been opened by the falling away of a mass of rock which now forms an embankment of the pool which is above the sea-level. At Haéna the shore road ends in rock wall, and the only passage along the western coast is by water.

The district of Haleléa which extends from Haéna to Mauna Puéo, a distance of fifteen miles, is the most fertile and best watered on the Hawaiian Islands; and eastward of Waiòli the valleys are wider and the ridges lower, more rounded and covered with a deeper soil, rendering this a region admirably adapted for agricultural purposes, although the frequent rains, extending over nine months of the year, are said to injure certain crops. Hanaleì is reputed the place on all the group where the rain falls oftenest and most abundantly. The upper ridges are heavily timbered, and four or five miles above Hanaleì the soil becomes black and marshy, and the Ohia trees (*Metrosideros polymorpha*) attain a circumference of twenty-five feet three feet from the ground. Further than this the natives consider the way to the summit impracticable, owing to the closeness of the vegetation and the swampy nature of the ground.

Kalihikaì and Kalihiwaì are valleys of little depth, well adapted to the cultivation of rice and kalo from the deep fertile soil, and abundant supply of water. Here, as elsewhere when not occupied by trees, the soil of the ridges is red, and when wet is very clayey and slippery; it supports a coarse grass, not very nourishing to the cattle.[1] At Kilauéa, six miles east of Hanaleì in the district of Koolaù, the coast is an abrupt pali of inconsiderable height, and of an intense red color; a small island near the shore has been considered the remains of an ancient coast crater, but is probably only a portion of the cliff which has been cut off by the waves, an agent which the natives say is constantly reducing its size. In many

[1] In the *Journal of the Boston Soc. of Nat. Hist.*, vol. iv. p. 147, Mr. J. P. Couthouy has described the stratification in this neighborhood near the shore, and expresses the opinion that "These laminæ were evidently formed by successive horizontal depositions, but have since been tilted up so as to dip about 5° north to the sea." From a careful examination of the place I am convinced that no tilting has taken place, but that the reef has been elevated, and the inclined strata of coral refuse, sand, and soil are the combined result of wash from the valleys and sand and coral fragments driven in from the sea by storms of unusual violence. It must be remembered that this is on the windward shore, and peculiarly liable to incursions of the sea as well as rain torrents.

places in this district the elevated coral-reef forms the roadway, and the coral-sand has often blocked up the mouths of the small streams which are compelled to seek another outlet through the porous reef beneath the surface, and the traveller may pass over the breach after a storm unconscious of the existence of a watercourse until his horse commences to sink in a quicksand.

Very curious masses of black basalt occur imbedded in ochreous earth in the hills near the shore. They often exhibit a columnar structure, are always smooth on the surface, as if long exposed to the action of water, and are seldom found in masses of more than two tons weight.

The southern boundary of Koolaù is formed by Mauna Kalaléa, a curved ridge meeting Mauna Puéo nearly at right angles. Its peaks are sharp, thin, and needle-like, about a thousand feet in height, often columnar. Near Anahòla, the ridge ends rather abruptly, and is so thin that a round hole has been formed through the wall high up the slope, through which the sky may be seen, from a base line of more than a mile at an average distance of half a mile. The dip of this ridge is quite regular seaward. From Anahòla southward the mountain slopes are more gentle, not so much broken by ravines, and the streams of water are small. Seven miles beyond is the Wailùa River, the second in size on Kauaì, and navigable for canoes two miles and a half from its mouth, which is sometimes nearly closed by a changeable sand-bar which reduces its breadth from one hundred and fifty to twenty-five feet. Its depth does not exceed fifteen feet.

Two miles and a half from the sea on the western branch is a fall one hundred and sixty feet high, which, after a rain, presents a most beautiful spectacle as the river dashes over the rocks, finally leaping in a broad sheet of foam into a dark basin walled on either side by cliffs so steep and rocky that even the ferns and mosses which revel in the spray cannot cover the naked rock. These walls continue nearly to the sea, and often present a columnar structure. One of the layers of basalt on this river is convex in the manner of a lava bubble, leaving a cave underneath. The fractures in this rock seem to follow nearly the course of radii drawn from the centre of the sphere of curvature.[1] The cave underneath the fall seems to be of similar structure, but can only be examined during very low water.

Several dykes intersect the high walls of the gorge about a mile from the sea, where the river changes its course. They are from three to six feet wide, and seem to have the direction of radii from the centre of the Island. On the eastern branch of the Wailùa is a fall of exceeding beauty.

Both above and below this the river passes through a deep cañon with nearly inaccessible walls. The whole region about these falls abounds in small cones, some of which have crateriform cavities at the top, several are broken down, and many of them are wooded to the summit. Probably this region was once a *malpays*, quite like that described by Humboldt as surrounding Jorullo in Mexico.[2]

The Wailùa intersects a mountain ridge about half a mile from the sea, which presents many curious features. The northern part is about six hundred feet high, extending two miles, and is called Mauna Nóunou, while the southern ridge, Mauna Kápu, is about two thirds this height and extends double the distance. Both of these ridges are nearly parallel with the coast line, are uneven, much degraded, and face the interior of the island with an abrupt wall. The stratification is not very apparent from the decomposed state of the lava,

[1] *Geology of the U. S. Expl. Exped.*, p. 269.

[2] *Vues des Cordillères*, pl. xliii. p. 239.

but the dip is towards the sea in every part examined, and sometimes exceeds 10°. Dana noticed, in a height of one hundred and fifty feet, ten layers each from ten to thirty feet thick.[1]

South of Nawiliwíli, and separating the district of Púna from that of Kóna, is a ridge of similar appearance, but much greater height (2290 feet by triangulation). The side towards the north is steep and generally inaccessible, except where two breaks occur, the western one affording an excellent roadway. So far as examined the dip was towards the south, about 10°–12°, and the seeming dip on the northern side was due to the successive deposits of wash from the mountains.

The region between Mauna Kaleléa on the north, Mauna Nóunou and Kápu on the east, and the Kolòa Ridge on the south, forms a semicircle of about seven miles radius, elevated about two hundred feet above the sea, and is mostly rolling land covered with grass and occasional groves of pandanus or koa (*Acacia koa*). Near Kolòa at the south-eastern end of the island, is a very interesting region where the volcanic fires have left their latest traces. Over nearly ten square miles the lavas are fresh and but little decomposed, although the cluster of craters from which it probably came occupies but a tenth of that space. From the Kolòa ridge to the sea the *pahoehoe*, or smooth lava, extends, in some places covered with large blocks lying loosely together, or with a red earth which nourishes a few argemone, sida, and indigo bushes. This barren surface is uneven, being in many places bulged up in immense bubbles some of which have fallen in, leaving caverns, one of which near the shore is paved with the ancient coral reef.

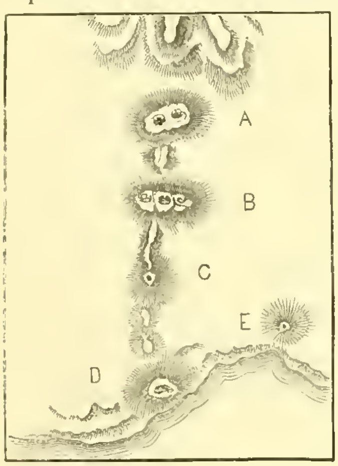


Fig. 1, Plan of the Kolòa Craters.

Dana's description of these craters is very complete, and leaves little to be added. He says:[2] "The old crater (C) has a steep and ragged summit, consisting of dark-brown lavas and scoriæ The cone stands about one hundred and fifty feet above the plain. The bare sides are smooth until near the summit, where the lava breaks out in columns, so rude and jagged as scarcely to justify the term, yet appearing columnar from below. It forms a narrow wall, or crest, broken by numerous rents, and is mostly wanting on the east-south-east and west-north-west sides. The crater is about one hundred and fifty yards wide at top, and has a depth of thirty or forty yards. The surface within is smooth, and consists of red earth like the lower slopes of the interior. The lava of the crest owes its roughness, in part, to a thin laminated structure and numerous vertical fractures. The laminæ are from half an inch to two inches thick, and although not easily separated, they stand out prominent over the worn or decomposed surface. The rock has been rendered very irregular from disintegration, and, at top, the columns are sometimes unevenly tapering. Besides these sources of its rough features, the walls within are covered with lava in twisted shapes, forming patches plastered on the surface, or hanging in stalactites. The rock of the crest is very cellular, and much of it is scoriaceous.

To seaward from the old crater, the observer looks down upon a low, broad elevation (D), with a shallow crater at top. Its smooth surface, covered with scanty vegetation, at first suggested that the lava had not flowed from it. But the crater proved to be half filled

[1] *Loc. cit.* p. 270. [2] *Loc. cit.* p. 273.

with black basaltic rock, lying in huge blocks, averaging more than a cubic foot in size. There were no scoriæ about the crater. The lavas were ejected, and subsequently cinders were thrown out, the decomposition of which covered the exterior with earth. The rock resembles that about Kolòa.

"A little to the east of north from the old crater, there are two hills, of oblong form, and about one hundred and eighty feet high. The near one (B) contains three craters, and the other (A) two. These are alike in their red, earth-covered declivities, unfurrowed by a single ravine or depression. The central crater in B, has a diameter of a hundred yards. On one side the lava is piled up in columns, somewhat as in the old crater; the bottom of the cavity is very evenly concave, and covered with red earth, like the exterior. The western crater is about half the diameter of the central, and has an earthy margin around the shallow cup-shaped cavity. The rock crops out in one place, and shows the same features as above described. Ejected cinders probably covered the lavas, as in other instances; the red color is the result of decomposition setting free the iron in a state of red oxide.

"In A, the larger crater of the summit is nearly two hundred feet across. The same red earth characterizes it inside and out. The smaller crater lies adjoining, and is forty feet across, and twelve deep. The walls around consist of cellular lava in layers which appear to have flowed from the larger crater; the rock is the same as that of the plains below. On one side of this small crater there is an entrance to a cavern which appeared to run down the hill; it could not be traced beyond thirty feet, on account of the rocks that had fallen in from above. The entrance is eight feet high and fifteen wide, and the walls are, in part, incrusted with lava stalactites. The cavity appears to indicate that a stream of lava had flowed from the small crater. There is still another depression on the western slope of this volcanic hill, that may have been a third crater." At present the large sand-hills on the shore have reached D, and partly filled it.

Near these craters the sand-drift has formed large deposits more or less consolidated, which have been worn into the most grotesque forms, sometimes resembling branching coral both in color and hardness.

The blowholes on the shore cliffs have attracted the attention of all travellers. At half-tide, during a heavy sea, the largest one throws up a column of water to a height of over sixty feet, from an orifice five feet in diameter; and the effect of the air rushing through the small crevices is very startling to the bystander, who feels the rock tremble beneath him, with groans and shrill shrieks, as the surf comes thundering into its midst. These caves are sometimes bubbles in the lava stream, and sometimes seem to have been formed by the washing away of loose scoriæ underlying the solid lava.

All the lava of this neighborhood is dark-red or brownish-black ferruginous basalt of solid appearance, and contains very little chrysolite. Near a small brook in the village of Kolòa, the lava assumes a prismatic structure, the prisms being from ten to eighteen inches in diameter, having from five to seven sides, and are more regular than any others seen on Kauaì.[1] Horizontal fractures are flat instead of convex, and the part adjoining these transverse fissures, is harder than the interior, and forms projections on the sides of the exposed columns; but where the ends are exposed to the weather they are convex from the abrasion of the edges.

[1] My friend Mr. Sanford B. Dole, a resident, informs me, since the above was written, that the columnar structure is much more perfect near Huleìa north of the Kolòa Ridge.

West of this lava region are many round smooth grassy hills of no considerable elevation, composed of red earth, and destitute of any depression on the top. The intervals between these hills are generally swampy, or the beds of winding sluggish streams. Beyond these the land becomes dry and barren near the shore, owing to the slight amount of rainfall on the lee side of the mountains. A few streams find their way down from the heights above, and the Wahiawà runs over a stony bed several miles in extent, from a very beautiful cascade in the mountains.

On the southern side of Kauaì opposite to Hanaleì is the valley of the Hanapépé, — a type of a certain class of cañons common on the Hawaiian Islands.

For two or three miles from the sea the river is several hundred feet wide, ten feet deep in some places, with an even bottom, and winds through a nearly level valley bounded on either side by cliffs two hundred feet high. These cliffs are nearly perpendicular, much grooved vertically, and present fine layers of basaltic conglomerate and gray basalt. This plain produces the kalo and bananas which supply the neighboring country, and is thickly dotted with the grass houses of the natives. It is a mile wide and four miles long. Beyond this the bed of the river becomes steeper, and the mountain walls close in upon the stream, forming a cañon a thousand feet deep. The walls are by no means even and unbroken, but here and there steep ravines and arched recesses, Gothic clustered columns and broken buttresses, astonish and delight the explorer, while the solemn stillness, broken only by the ripple of the stream over its rocky bed, completes the illusion of some vast aisle of an ancient temple.

The stream of cold clear water winds from side to side, constantly cutting off the pathway, and receiving from the heights above a tributary waterfall. The walls rise generally clear from the bottom of the valley; the agent that formed the gorge has removed all debris; even the little ravines that open on either side do not accumulate any wash in the main bed. This is doubtless owing to the force of the Hanapépé which, during the rains, often fills its channel from wall to wall, moving stones of considerable weight with its impetuous current.

After a ride of four miles through this cañon, the fall is reached, and horses can go no further. The pali on the right curves round and closes the chasm with an abrupt wall over which the stream pours from a height of three hundred and twenty-six feet. Two high, sharp, and somewhat inclining peaks stand on the left, forming a colossal gateway for a small stream which enters from a broader valley beyond. All around the circus of the falls small white cascades dart out among the dense foliage, sometimes spreading like fingers over the black rock they in vain endeavor to conceal, or side by side in a large company, like the burnished pipes of some vast organ, warble forth an accompaniment to the diapason of the fall. The effect of the light, sunny-green foliage of the kukui, contrasted with the dark green of the orange and coffee overhanging the stream, is very pleasant in a place where only the noonday sun penetrates.

A curved fracture is quite evident behind the fall, although the columnar structure is no longer so evident as when Dana visited the place. Several large dykes occur two miles below the fall, extending through the whole height of the cliff on the right bank of the stream, although their existence is concealed by dense foliage on the left. They seem to proceed, like those in the Wailùa valley, from the mountain towards the sea. Where the gorge opens upon the plain a beautiful example of prismatic structure was observed.

A small spur of the wall exhibited the appearance represented in the margin. Three layers of gray cellular basalt were capped by the soil formed by the decomposed scoriæ of the bed above, and formed terraces which were covered with grass and convolvulus vines forming a curtain over the dark rock beneath. The prisms were very irregular, none having parallel sides. Near this terrace, one of the streams of prismatic lava had passed over a rounded mass of lava resembling blue clay, fissured as in the figure.


Fig. 2. Cliff in Hanapépé Valley.

The Waiméa River is similar to the Hanapépé, but larger, and its valley is neither so deep nor so picturesque, but it is nevertheless an oasis in the barren red plain of this part of Kauaì, and its green kalo-ponds and banana plantations furnish the principal food of the inhabitants of the village of Waiméa, which is situated on the dry plain at the river mouth. Canoes pass up the river several miles, and at its mouth it is too deep for fording. It rises on the uplands of Napàli, but receives some tributaries from Waíaleale.

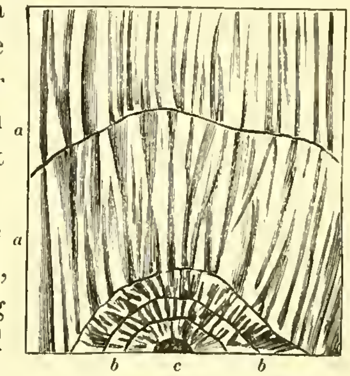


Fig. 3. Natural Section in Hanapépé Valley.

a, a, prismatic basalt; *b, b,* blue stone with concentric coating much fractured; *c,* solid amorphous nucleus.

Beyond Waiméa the mountain region of Napàli approaches the shore, leaving a narrow strip of land usually less than a mile wide, without permanent surface stream, but abounding in springs along the shore near the sea level, which supply large kalo-ponds, and water fields of sugar-cane, cocoanuts and bananas, forming a green belt between the ocean and the dry and rocky slopes of the mountains. Anywhere over this land water may be obtained by sinking wells eight to fifteen feet deep, and large tanks are dug to water the herds pastured on the scanty beach grass.

Waiméa is the usual place to ascend the mountain. The table-land to the west is wet, and during the rainy season dangerous without guides. Since the introduction of horses, the path across Napàli has been quite forsaken, and few old natives know the way. Several caves occur near the centre of the plain a little west of the pathway. Dr. Charles Pickering, in crossing the island in October 1840, passed along the course of the Waiméa River some miles through an exceedingly interesting botanical region, but on reaching the table-land found it very difficult to pass, owing to the marshes and quagmires which abound over a tract twenty miles square. This was in a favorable season. Waíaleale has been seldom ascended, although the ascent is possible from Hanaleì and Lihùe as well as from Waiméa. The summit is an extensive bog like Napàli, abounding in deep mud-holes, and several natives having lost their lives there, it is difficult to obtain guides or even bearers to ascend except during very dry seasons, as in September.[1]

Ten or twelve miles west of Waiméa in the district of Mána, the coral reef has been elevated in a long wide ridge transversely to the present shore line. It is much fissured, as if a stream of lava had forced its way beneath it. Near Lápa, in this same district at the south-western end of the Pali, is a very curious sand-bank formed by the wind and currents which strike the island here with great force. This bank is nearly sixty feet high,

[1] The author found it impossible, even with the offer of five times the usual wages, to obtain guides in July 1865, although the streams were low and the weather favorable.

and is constantly advancing on the land, the front wall being of as steep an angle as the sand will permit; the same angle is preserved from top to bottom, without the slightest debris at the base. The sand is white, coarse and composed of coral, shells and lava. When two handfulls are slapped together a noise resembling the bark of a dog is heard, the place being known as the "Barking Sands." This phenomenon also occurs near Kolòa and at other places, but requires that the sand be very dry. It is a common amusement for visitors to slide their horses down the steep incline, when a noise as of subterranean thunder is heard, which greatly terrifies animals not used to the experiment. The mirage is often seen on this dry hot soil so perfectly, that strangers endeavor to ride round the extensive lake they see before them.

No scientific observers have examined the western pali thoroughly. The water is very deep close to the shore, and the walls so perpendicular that canoes often pass between the rock and the waterfalls, which are common after a rain, and sometimes strike the sea twenty or thirty feet from shore.

NIIHAU.

Fifteen miles from Kauaì is the Island of Niihau, which is different in many respects from other islands of the group. It is twenty miles long by five wide, and consists of two portions, the mountain region, and the plain which meets this on three sides, the latter so low as to be almost invisible from Kauaì. The mountain is not much channelled by the rains,

Fig. 4. View of Niihau from Waiméa, Kauaì. On the left is Kaúla, on the opposite side Lehùa.

which, however, are infrequent from the leeward position of the island, nor are the lower slopes covered with vegetation; small shrubs, (*Compositæ*, *Euphorbiaceæ*, *etc.*,) and succulent plants, constitute nearly the whole flora, indicating a dryness of the soil. The summit is remarkably flat in a distant view, but on closer inspection appears undulating and irregular, but wholly destitute of sharp peaks and narrow ridges. There is said to be no evident crater. On the windward side the mountain meets the sea in a pali of nearly eighteen hundred feet, exhibiting evident stratification. The rock is quite identical with that of the western part of Kauaì.

The craters of Kaúla and Lehùa belong to this island, and the latter is separated from Niihau by a channel only half a mile wide, and one and a half fathoms deep, in which the connecting bed of lava is plainly visible through the clear water. This lava is dark, in layers of about a foot in thickness, and seems to dip toward the north-west. Lehùa is mostly composed of tufa, has a crater much broken down towards the south-west, and a spring of good water. A colony of rabbits has for some years held undisputed possession, and is said to have increased rapidly.

Kaúla (*The Red*) is further from the opposite end of Niihau, and except in very smooth seas is difficult of access. It has no water, and is wholly barren. On the shore of Niihau, opposite these islands, are shore craters, especially near Kaúla. They are composed of red tufa, and although much broken down, exhibit clearly the anticlinal axis of true tufa cones. In the tufa, chrysolite and small clusters of calcareous crystals occur, and also fragments of coral reef.

The plain land of Niihau comprises two thirds of its surface, and all the habitable part. It is composed of coral reef, sand, and the wash from the mountain in successive layers. Although destitute of running streams, the soil is fertile, producing under cultivation the best pine-apples and bananas found on the group, as well as indian-corn, beans, cabbages, onions, squashes, and most of the vegetables of temperate climates.

The coral reef has been elevated from fifty to one hundred feet, and at the south-east end of the island is quite level, indicating that the rise was not gradual. This level portion is bare and very hard; the coral structure is not evident, its fracture is conchoidal, and it has a metallic ring. The surface is very uneven; the large caves and channels, always found in such formations, are here filled with breadfruit-trees and sugar-cane, which grow well in these pits, which are sometimes twelve feet deep and a hundred in diameter. They seem to be rooted on a base of lava or scoriæ, and only the topmost branches of the breadfruit-trees appear above the coral bed, the cane being usually wholly below. The rich deposit of vegetable mould in these pits would indicate great age, and it is worthy of note that the cane which grows here on little else than silica is harder, and leaves more ash than that on the richer plains of the other islands.[1]

Opposite Kaúla the reef is covered with sand in round hills which have a thin crust of earth in which grass grows well. Wherever the wash from the mountains has accumulated, sweet potatoes and yams grow abundantly. In a well sunk in this region, the earth was three feet deep, the sand five, and the coral reef beneath this contains water which is slightly brackish. In all places where exposed, the stratification of the sand indicates a wind rather than a sea deposit, probably filled up subsequently to the elevation of the reef. On the leeward side of the island, near the centre, are fresh-water ponds covering several acres very little above the sea-level. Salt-ponds occur at the southern end of the plain, where formerly the natives gathered much salt.

In some places the hard lava crops out, although no flow has been traced to the mountain, and is sufficiently hard to hold water. The natives in ancient times, further back than tradition extends, built reservoirs to hold water, some of which have been recently discovered, and are in good repair.

The absence of craters on the mountains of Niihau seems to have been settled by several natives who frequently make the ascent, and assure us that there are no valleys nor breaks of any size. None can be seen from below, and as there are no forests to conceal the irregularities of the slope, it would not be difficult to discover from the shore any true craters or large rents. On the other hand the dip is quite regular so far as examined, from the high wall fronting Kauaì to the opposite shore. As the cliff is on the windward side of the island comparatively little rain falls on the lee slopes, and in consequence there is but little soil and a scanty vegetation.

[1] The crushed cane called *trash* or *bagasse*, is used as supplementary fuel under the train of sugar-pans, and the silica is melted into spongy masses of glass.

The channels between the different islands are deep and quite irregular, so far as soundings have been made. These have been limited to the principal harbors and shores where shoals were suspected. Generally where rock cliffs meet the sea, the water is deep and the shore destitute of coral reefs. Where a sand-beach or low lava streams are found, the fringing reef extends some distance from the shore, but it is generally quite level to its outer edge where it meets deep water at once. The limits of these reefs may be readily seen by the marked change in the color of the water. In none of the channels are there known to be detached coral reefs; there seem to be no sunken rocks at any considerable distance from the shore which might indicate the existence of some submerged or abortive volcanic peak. It is well known, however, that to the north-west of the Hawaiian Group, a long range of shoals extends many hundred miles, but beyond the mere fact of its existence, we know nothing. It would be most interesting to institute a series of soundings to the south-east of Hawaii, and it is hoped that the Hawaiian Government will undertake a complete hydrographic survey of the "Seven Seas."

OÁHU.

(See Map Plate XII.)

General Description.—Oáhu is ninety miles distant from Kauaì, in a S. E. direction, the channel between being called Ieiewàho. Its shape is somewhat irregular, the greatest length being thirty-five miles, the breadth twenty-one, and the area six hundred square miles. Unlike Kauaì, Oáhu has no central mountain, but on the N. E. and S. W. coasts, two high ridges extend in a nearly parallel direction for many miles, the plain between being the base of the N. E. or Konahuanùi range.

The windward side of the island is well watered and fertile, and even the leeward side possesses several streams besides many subterranean springs. As on all the other islands of the group, except perhaps Kauaì, the larger portion of the surplus rainfall passes to the sea by subterranean channels, often appearing as springs near the line of low tide. The lava of the mountains is more porous and less decomposed than on Kauaì. Dykes are not so common, nor so large, nor have the valleys such high and closely approaching walls, with the single exception of the valley of Kaliiwàa.

The shores of Oáhu are mostly fringed with coral reef which is often half a mile or more in breadth, and is composed of the cemented coral fragments, shells, sand and growing species of zoöphytes. The ancient reefs are elevated thirty, forty, or even a hundred feet in various places, and several of the valleys have by this barrier been changed from lagoons to solid ground. Volcanic action is perhaps more evident than on Kauaì, although many ages must have elapsed since any outbreak. Vegetation extends to the summits of the mountains, and during the rainy season even the dry plains and tufa cones support a crop of grass.

South-west Range.—The mountains on the S. W. were perhaps the earliest formed, and from the overlying strata of the eastern range, it is evident that they first ceased to give out lava streams. They are much broken into peaks and ravines, the slopes are steep and difficult to ascend, the summits are often marshy, and on one of them a lake of some size is said to exist. This range is usually called the Kaàla from its highest peak, which Dr. Gairdner ascertained to be three thousand eight hundred and fifty feet high (3850). There are two breaks or passes, one to the south of Kaàla, only fourteen hundred feet high, while the other near the southern end is sixteen hundred.

Between the mountains and the shore is a narrow, desolate, stony region called Waianaè, above which Kaàla towers with abrupt precipices strengthened by narrow buttresses, and generally inaccessible. In various parts of Waianaè are detached hills composed of a hard lava of various colors, some of it quite similar to the clinkstone found on Hawaii, while most of it is peculiar to this place, becoming white on decomposition, and so soft as to serve for chalk. This white formation is quite distinct from the decomposed coral reef which is sometimes found near by. The whole appearance of this barren, desolate district, without streams, and almost without vegetation, hedged in towards the land with dark red cliffs two thousand feet high, bending on either hand towards the shore, is that of a vast crater broken down towards the sea.

The pass near Kaàla exhibits several fine dykes, in one place eleven occurring within fifty yards, some projecting from the softer wall of the precipice, while others have broken out leaving narrow slits in the rock. A conglomerate is very common near by, as are also the small boulders with concentric coatings mentioned in the description of Kauaì.

Towards the centre of the island the slopes of the Kaàla mountains are less abrupt although still quite steep, the valleys are deep, although of small extent, and the ridges so sharp in many places as to render walking decidedly dangerous in wet weather. The rocks are mostly of gray basalt alternating with a red cellular lava. They are often porphyritic, containing small tabular crystals of feldspar.

These mountains completely cut off the trade wind, and are much dreaded on this account by mariners on their voyages to and from Kauaì. At Barber's Point (Laelóa) the sand extends some distance from shore, forming a rather dangerous shoal.

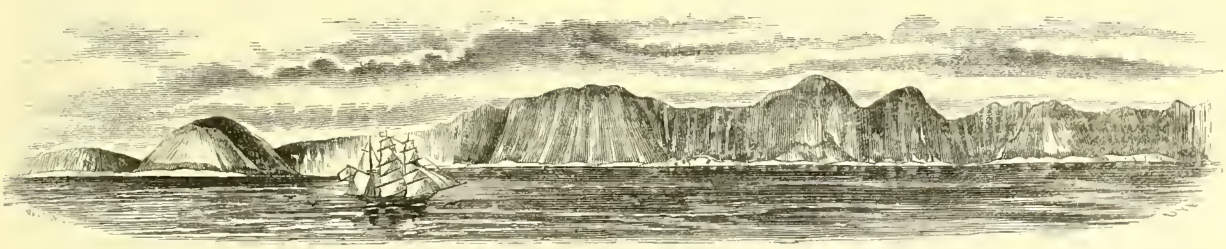


Fig. 5. Eastern end of Oàhu. From the north, distant fifteen miles.

North-east Range.—The mountains of the Konahuanùi range are higher and much more extensive than those of Waianaè. Commencing at the northern end of the island near Kahúku, the mountains rise gradually with a slope of less than eight degrees for nearly ten miles; then the summit becomes broken and jagged, valleys of increasing size cut the mountain to its core on either side, until it culminates in the two peaks of Waiolàni and Konahuanùi, four thousand feet above the sea, and which seem rent asunder to form the valley of Nuuánu. Beyond this towards the east the valleys decrease in size on the leeward side, while on the N. E. an almost perpendicular wall extends for thirty miles unbroken by any valley, ending at last abruptly at Makapùu Point. The range is simply a midrib some thirty miles long with a complete series of lateral ridges or pinnæ on the S. W., but without these for two thirds its length on the N.E.

The valleys are of exceeding beauty, and many travellers have pronounced the scenery unsurpassed by any in the world. Nuuánu opens on the coast not far from the centre of the range, directly behind Honolulu, and was once a bay or lagoon, protected towards the sea by a reef of coral a mile wide, through which the fresh-water streams from the valley made their way. This bay was nearly two miles deep and of the full width of the valley. The elevation of the reef some twenty-five feet has furnished a site for Honolulu which covers its whole width, and has converted the bay into a low but pleasantly situated plain. Near what was formerly the head of the bay, the stumps of large tree ferns have been dug up from a depth of five to ten feet, in such quantities as to serve for fencing material on a small cane-field. No such ferns are found at present north of Hawaii.

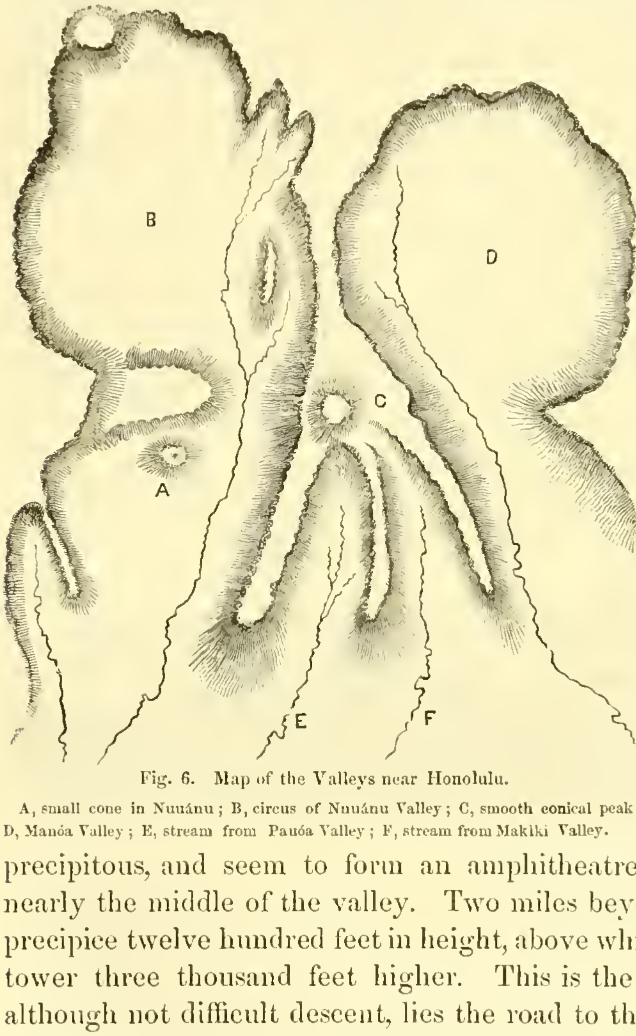


Fig. 6. Map of the Valleys near Honolulu.
A, small cone in Nuuánu; B, circus of Nuuánu Valley; C, smooth conical peak; D, Manóa Valley; E, stream from Pauóa Valley; F, stream from Makiki Valley.

Ascending the valley by a gentle slope among the gardens of the foreign residents, and the equally beautiful kalo-ponds of the natives, one sees the ridges on either side, at first broad and smooth, covered with grass; but soon these ridges become steeper, their walls rise nearly perpendicularly, fluted with the pathways of the rain torrents, mantled with every shade of green, and fringed at their base by dark densely wooded dells. The origin of Gothic architecture is referred to the study of the form of trees, but here the Divine Architect has reared a structure far more suggestive than the forests; and the green archways of covered rock extend in long colonnades up the aisle leading to a nave crowned by the spires of Waiolàni, the "waters of Heaven."

The valley becomes narrower, although never a gorge; and about four miles from Honolulu, a low ridge crosses the road, beyond which the walls are higher, more precipitous, and seem to form an amphitheatre around a small cone crater which occupies nearly the middle of the valley. Two miles beyond, the valley terminates on the brink of a precipice twelve hundred feet in height, above which on either hand Konahuanùi and Waiolàni tower three thousand feet higher. This is the famous Pali of Nuuánu, down whose steep although not difficult descent, lies the road to the district of Koolaù. The cliffs near the Pali are much worn by the rain and wind which sweep through the narrow pass with terrific violence during a storm, and several hills of red ochreous earth are ground and channelled by the same agency into forms resembling those described in Colorado by Dr. J. S. Newberry.[1] Two dykes occur in the hard graystone of the cliff, and several rents at right angles to these have formed small ravines. There are some indications of volcanic action in the neighborhood, as scoriæ and cinder deposits, but they are probably much older than the shore craters. No distinct crater is visible, although the sides of the valley much resemble the encircling

[1] Report on the Colorado, by Lieut. J. C. Ives. Part iii., p. 82, *et passim*.

walls of some vast pit. On opposite sides of the valley there is very little to indicate that they were ever nearer to each other than at present; they are not always of the same height, their spurs and side ravines are different, but the arrangement of lava beds and their dip is essentially the same.

In Nuuánu Valley at the head of the ancient bay, and along the base of all the ridges towards the east, a coarse black gravel is found at various depths, owing to the irregular surface of the ground, but apparently nearly on the same level, in layers of one or two feet in thickness. This gravel seems to be comminuted pitchstone, and contains a very large amount of iron. It is often used to cover road-beds, and when crushed by the unshod hoofs of the horses, forms a coarse powder, and an electro-magnet drawn through it for ten inches becomes charged with particles of iron. The wash of the hills and the tufa of the coast craters is often directly superimposed upon this bed. Near the lower end of Nuuánu a stream of dark compact basalt crops out in the bed of a river, exhibiting rude columnar forms.

Next to Nuuánu on the east is Pauóa, a small but very beautiful valley filled with rice-fields, kalo-ponds, banana plantations, and the grass houses of the natives, and remarkable as affording a pathway for horses to the summit of the mountain at its head, the valleys of the Hawaiian Islands usually ending in an abrupt wall often inaccessible to man. East of this, Manóa Valley forms a broad circular plain inclosed by high and steep walls. The soil is deep and rich. The rock is usually a gray or red cellular basalt, which becomes quite soft on decomposition, so that when wet it may be easily cut with a knife, though when dry it is as hard as an ordinary unpressed brick. It retains the shape of its nearly spherical cells through these changes which must take place several times each week, as the showers and sunshine alternate with wonderful rapidity in these mountain recesses. In many places large bubbles have been formed in ancient lava streams which now form caverns, sometimes of considerable extent with rough sides and roof. These are often exposed by the breaking off of the outer wall, and have for ages formed convenient receptacles for the dead.

The spurs of the side ridges project towards the mouth of the valley usually, but in several remarkable instances the direction is reversed. During the rains, the circus at the head of Manóa presents a hundred cascades whose white threads may be seen several miles at sea. The ascent to Konahuanui by the western ridge of Manóa is not difficult, although beyond the first few miles the pathway becomes narrow in places, and the ridge almost knife-edged. Swamps and pools are met with on the way, and the whole soil is wet, even to the summit, where moss covers the trees, and is usually saturated with water from the clouds that settle upon the mountain. Two cracks or rents occur, neither of them of any great size, but remarkable for their position. They are both about twenty feet wide, and nearly the same depth, the bottom being filled with loose earth and stones. The rock exposed by these sections is the red-brown cellular lava which crops out below, and the strata are much confused as if different streams

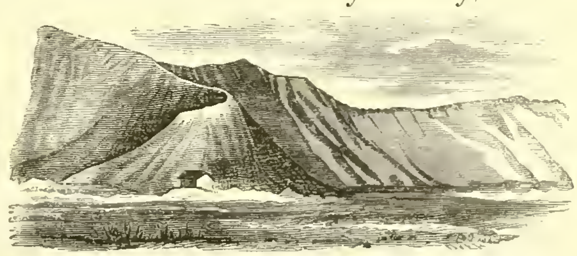


Fig. 7. Side Ridge in Manóa Valley.

Fig. 8. Cracks in the Manóa Ridge.

had met here. The soil is in many places quite red from the oxide of iron, and the water in the pools is often coated with the iridescent film of the hydrated peroxide.

In the valley of Palòlo the decomposed lava has formed a stiff, tenacious, light-colored clay which constitutes so large a proportion of the soil as to give the valley its name. Towards the east the valleys are small, destitute of running streams, and the ridges point inward as in the figure. Caves are more frequent near this end of the island, and some are of considerable extent. The soil is red, dry and covered with loose stones. In ancient times this barren land was cultivated, and the small piles of loose stones show where the sweet-potatoes were planted, the stones retaining moisture, and serving as supports. At present, wild cotton (*Gossypium tomentosum*), a few *Convolvulaceæ*, sidas, and argemones constitute the vegetation during the summer. There are no trees, save a few Nawiliwili (*Erythrina monosperma*).

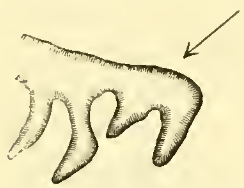


Fig. 9. Plan of the Makapúu Ridges.

The mountain ends abruptly at Makapùu, and the only pathway leads over an almost perpendicular precipice nearly eight hundred feet high. From this the whole aspect of the island changes. The deep valleys like Nuuánu and Manóa, and the sterile rock-paved region of Kóko, have alike disappeared, and a narrow strip of bright green land extends for eight or ten miles, bounded on one hand by the green ocean, and on the other by an almost unbroken wall nearly two thousand feet high. A section through the island here at right angles to the main ridge would be approximately represented by the annexed diagram.

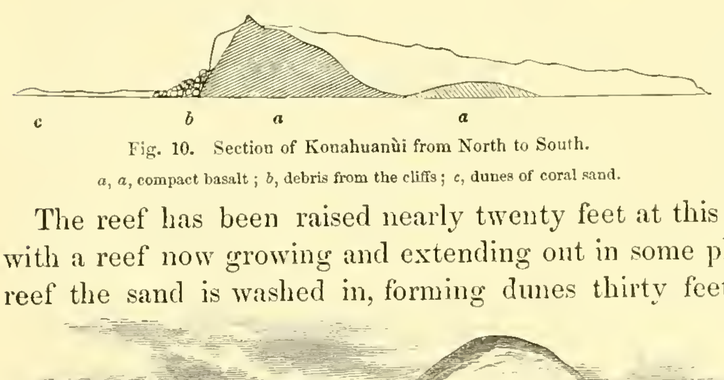


Fig. 10. Section of Konahuanùi from North to South.
a, *a*, compact basalt ; *b*, debris from the cliffs ; *c*, dunes of coral sand.

The summit is a very sharp edge through which many holes are visible from beneath, and the base is covered with fallen rocks and earth so as to furnish a pathway for the goats to the top.

The reef has been raised nearly twenty feet at this point, and the whole coast is fringed with a reef now growing and extending out in some places four thousand feet. From this reef the sand is washed in, forming dunes thirty feet high in some places, of a dazzling whiteness. There are several small islands off the shore, evidently the remains of tufa cones; the largest is represented in the accompanying figure.

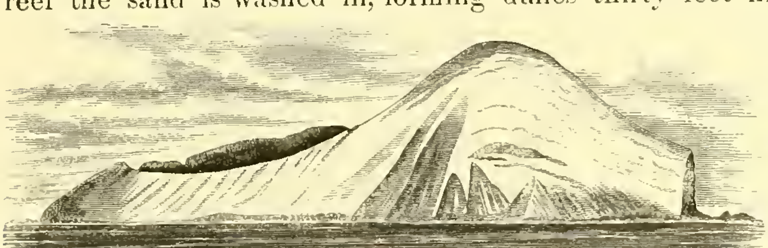


Fig. 11. Island Crater off the northern coast of Oáhu.

The pali of Koolaù is one of the most remarkable formations on Oáhu, and the interest with which it is regarded by geologists is much increased by the explanation Prof. Dana gives of its origin.[1] It must not be inferred from that explanation that this wall is a clear unbroken perpendicular precipice of regular curve. Whatever may have been its condition a quarter of a century since, at present there is a considerable talus at the base, composed of fragments of rock intermingled with the earth washed from above. It is quite difficult to ascertain the dip of the exposed strata, as the cliffs are quite inaccessible. From below they certainly seem to dip towards the

[1] *Loc. cit.* p. 258.

interior of the mountain, and this is particularly the case in the projecting buttresses. Low ridges run out like projecting arms, often encircling crater-like valleys. This is especially common through the region from Waimanálo to Kaneóhe. Two ridges, one of them nearly two thousand feet high, extend completely to the sea enclosing the district of Kailùa, and between these occur many circular depressions with smooth rounded walls, and hills of red ochre. The many brooks in this neighborhood have confused the original outline of these hills and valleys by cutting through them and sometimes nearly filling the hollows with alluvial deposits. The coast ridge is very sharp and needle-like, and must have occupied nearly the centre of Prof. Dana's supposed crater.

From Kaneóhe to Kahúku is the most fertile region of Oáhu. The soil is deep, well watered, and is covered in many places by fields of sugar-cane. Tobacco, cotton, and ground-nuts also do well here. Kaneóhe is directly opposite to Nuuánu Valley, and is remarkable for its series of coast craters. The main ridge changes its character beyond towards the west, and valleys and ravines cut their way into the interior of the mountain. A curious circular valley is directly opposite the village of Kaneóhe, and is a fair type of many valleys on the islands.

The strata evidently dip towards the N. E. as well as to the S. W., and in the valley of Ahumánu a fine spring gushes forth from the mountain wall in the direction of the strata. Farther to the west, the scenery grows wilder and more grand. The lateral ridges approach the sea; retaining, however, the identical appearance of the Koolaù Pali, their black, almost perpendicular rock-walls often being destitute of vegetation for eight hundred feet in height, and above and below this bare space clothed with dense foliage. At the head of Punalúu Valley is a large cone crater, from which radiate several valleys, as the Kahàna, Kaliiwàa, Punalúu, and others. This crater is densely wooded, and occupies nearly the centre of the range. No one seems to have ascended it, and it is impossible to say how deep the cavity may be, but the internal slopes as seen from below seem to be quite steep, and probably the outer wall is broken down. Around the base is a large swamp in which several streams take their rise, the Kahàna being one of the largest in Oáhu.

The adjoining valley of Kaliiwàa or Kaliuàa, much resembles that of Hanapépé on Kauaì. Entering the lofty portals which rise in pinnacles a thousand feet, the explorer finds himself in a dark and narrow aisle, less than sixty feet wide, and enclosed with inaccessible walls at least eight hundred feet high. A clear cold stream runs over the stony bed shaded by the dark green foliage of the ohia ai (*Eugenia malaccensis*, Linn.). In ancient times this was a place sacred to the native divinities, and even now, so impressive is the solemn grandeur of the scene, that the natives make an offering of a few leaves placed beneath a stone, that the wrathful gods may not hurl rocks from above upon the sacrilegious intruder.

A quarter of a mile from the entrance is one of the curiosities which gives the valley its name (Ka-lii-wàa, the chief's canoe). On the right, at the head of a small ravine, some fifty yards from the stream, is a perpendicular wall over which a former stream fell nearly three hundred feet; and the water has worn a perfectly regular, smooth groove, much resembling a cast of a native canoe. About a mile beyond this is a similar but more perfect channel. For nearly a thousand feet the vertical wall is cut into by a conical groove twenty-five feet wide and fourteen deep at the bottom, but regularly diminishing as it approaches the top of the cliffs. That this was formerly the bed of a stream, and that water was the sole formative agent, is very evident, although the perfection of the work, the smoothness of the sides, seem beyond the power of a rude waterfall. A few rods beyond this is the present waterfall, which has worn its way down from above until its waters gush out of a narrow cleft, clear of the wall, into a dark pool below, which only the mid-day sun ever shines upon, so close are the walls above it. There is no possibility of scaling the walls of the valley; and to examine the gorge above, one must retrace his way to the shore and ascend the ridges. There are two falls above this, one of them invisible but audible; the other, some three or four hundred feet high, may be seen from the shore some four miles distant. It may be a matter of interest to some future traveller to trace the ancient conduits, and see what has twice diverted the stream.

At Laié the drift-sand has formed hills of sand-stone hard enough for building purposes. These hills are thirty or forty feet high, much broken by earthquakes apparently, and worn by the action of wind and rain, into grotesque honey-combed masses and ragged pinnacles. From the white color of this stone it has often been mistaken for elevated coral reef. Near Kahúku the sand-hills are of greater size and height, and much resemble an elevated beach. The tracks of a plover, identical with the existing species, were discovered imbedded in the sand-stone nearly a hundred feet above the sea. The stone splits readily into slabs, and is white, hard, and of a coarse texture. The elevated reef near Kahúku, and all along the north-west end of Oáhu, is quite distinct and full of large caves. A light-colored rock in rounded masses is sometimes met with at this end of the island. It is a light, porous gray-stone, and always occurs beneath beds of red cellular lava.

The Shore Craters of Oáhu.—Although the main mountains of Oáhu exhibit few craters or cones in perfect condition, there are along the shores fine examples of tufa cones. These occur in six groups: at Kaneóhe, Kóko, Leáhi, Puawaìna, Aliapaakaì, and Laelóa.

Kaneóhe Group.

On the peninsula that forms the eastern side of Kaneóhe Bay are four hills, three of which exhibit craters. Excepting these volcanic hills the surface is flat and formed of coral limestone elevated but a few feet above high-water level. The largest crater (A) is much broken down by the sea; no lava stream has been discovered. The next cone towards the land (B) is almost wholly composed of a compact, black, heavy lava, which has flowed out towards the sea, although now wholly hidden by accumulating sand. The other two hills (C, D) are small, and made up of lava similar to the last. A crater (F) some rods from shore has not been examined; it much resembles the island off Makapùu. At E is a low ridge nearly covered by sand, which appears to be the remains of a crater nearly as large as A. Both C and D have been much worn by the waves on the sea front, while they have been covered by sand towards the shore, a fact that would render their identification difficult were it not for the description of Dana written some twenty-five years ago. This erosion has taken place in spite of the protecting coral-reef which fringes this coast. Along the shore to the west are one or two small islands of like origin, but much worn away by the sea which has obliterated all traces of craters.

Fig. 12. Plan of Kaneóhe Craters.

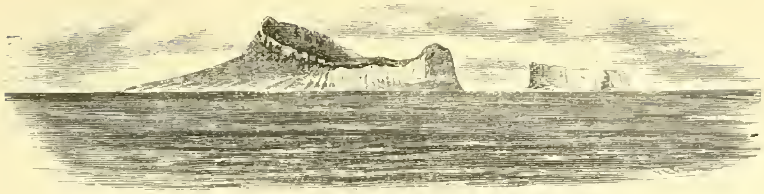


Fig. 13. View of Kaneóhe from the East.

Kóko Head Group.

The south-east promontory of Oáhu is composed of the remains of cones so closely crowded that the strata and slopes are very perplexing. Kóko is a smooth rounded eminence with no traces of a crater on the top. The ascent is remarkably gradual, and there is a good horse-path to the summit (A), where the grass grows well. Blocks of lava are scattered over the level top, probably brought there by the natives for burial purposes. At B is a small crater, now covered with grass; the walls are low, rounded, and smooth. D is open to the sea, and the blue color of the water indicates great depth; at its head is a house belonging to the king, and a spring (C) of fresh water issuing at the base of the cliff supplies several kalo-ponds. The walls are steep but not high. Near the signal station between D and E, there is a large amount of augite imbedded in the tufa, also incrustations and thin layers of calcareous matter. E is the largest crater, and its walls are broken towards the sea, leaving the bottom dry and level a few feet above high water. All through the tufa of this crater fragments of coral rock are thickly scattered. The tufa is hard, brown, and coarse, much resembling sand-stone; where the sea has undermined the cliffs, projecting striæ parallel to the dip seem to indicate varying hardness in the layers. Inland of this is a very high and steep cone quite different in its outline from the other craters in the neighborhood. The internal cavity descends nearly to the sea level, and is open towards the north-east. The cone is obliquely truncated, owing to the trade-winds, which, besides modifying the form in this way, render the plan oval with the acute end towards the wind, as during

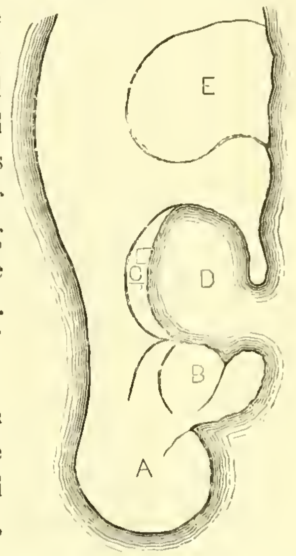


Fig. 14. Plan of the Kóko Craters. A, smooth grassy summit; B, small crater; C, spring of fresh water; D, deep crater open to the sea; E, large dry crater broken down towards the sea.

Fig. 15. View of Kóko Craters from the outer Signal-Station.

The bay in the foreground is represented by D on the plan (Fig. 14), and the small house on the right marks the position of the spring.

the eruption the ashes are blown to leeward. The windward side would, therefore, be the weakest, and is most easily breached. Lava streams are common about Kóko, although it is often difficult to trace them to their source, and both the graystone and red vesicular varieties are found, the former often imbedded in large fragments in the tufa, the edges being as sharp and uneven as if recently fractured.

Leáhi Group.

The most remarkable object on approaching Oáhu, is the high cone of Leáhi or Diamond Hill. It is situated on the shore nearly between Kóko and Honolulu, and about eight miles west of the former. Its height at present is from four to seven hundred feet,[1] and its longest diameter at the top, about half a mile. The crater is deep, reaching nearly to the sea level, and contains no lava rock. At the bottom, during a third of the year, a pool of water collects which covers nearly half of the tolerably level bottom; on the remainder, which is deeply furrowed by rains, wild cotton, a few sidas and argemones flourish, and enough grass to tempt horses to make the difficult ascent and descent.

Fig. 16. View of Leáhi from Punahoù (⟶East).

This cone is rapidly diminishing. In the winter of 1864, during a severe rain, when thirty-six inches of water fell in a week, a deposit of mud two feet in depth was formed over the inner basin, and the degradation of the exterior was still more extensive. The south-west end, which is the highest point, was formerly quite accessible, but now can only be scaled with ladders or ropes. Most of the exterior has been washed down upon the elevated coral bed which surrounds the cone, forming a deep layer of soil, frequently cut through by rain-channels. The strata exposed by the removal of the exterior, have a dip towards the centre, showing that the whole outside has been removed towards the south and west. The rim of the crater is narrow, and where the exterior slope remains, exhibits an anticlinal axis, the dip being about 35°.

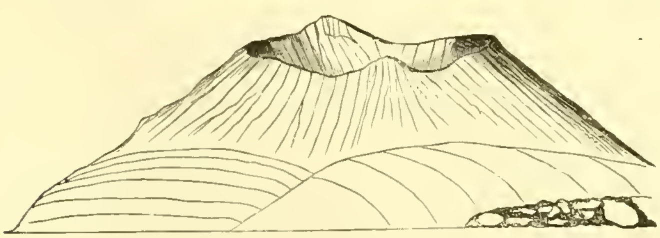


Fig. 17. View of Leáhi from Kóko (N. N. E. ⟶.)

The tufa of which the hill is composed, is light brownish, inclining in some places to red, and is very friable, breaking easily in the fingers. It consists of thin laminæ usually separated by a calcareous deposit. Coral of recent species occurs imbedded in considerable quantity, often undecomposed, and in masses of two to twenty cubic inches. The whole region about Leáhi is an elevated reef.

No lavas have issued from this cone, but two large streams surround it, and have poured into the sea at its base over a deposit of sand. The sand has been washed away leaving the lava in broken slabs. In one place this lava, in passing over a stratum of tufa, has

[1] Since the above was in print (1867), President Alexander, of Oáhu College, has found the highest point to be 760 feet.

baked it hard and given it a deep red color; at the same time its structure has been rendered beautifully prismatic, the penta-hexagonal prisms being about an inch in diameter and two or three long. The lava above is in a thin sheet, and probably cooled rapidly, as no effects of heat are visible half a foot from the surface.

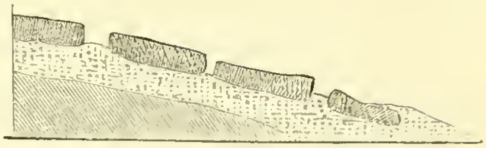


Fig. 18. Section of a lava stream at Leáhi.

There are two other craters nearly in a line with Leáhi, but low, and mostly composed of lava; probably they were the vents which supplied the lava covering this region. All the country in the neighborhood is dry and barren. Smooth beds of lava are covered with blocks of similar rock of all sizes from one to one hundred cubic feet, indicating that a lava flow had underrun and burst up a previous stream. Where a river from Palòlo Valley has broken through the deposit, three or four strata are visible near the base of the Konahuanùi range — their probable source. The coral reef is much cracked and tilted, and is of great thickness, some of the natural pits or caves being twenty or thirty feet deep with a coral bottom. The upper surface is rough, and so colored by the ochre of the earth in the neighborhood, as to lose all appearance of organic origin, and to closely resemble lava.

Puawaina Group. Punch-bowl, or Fort Hill, is directly behind Honolulu, adjoining the west ridge of Manóa Valley, and blocking the entrance to Panóa. It much resembles Leáhi, but is much smaller. Its brown tufa sides have an arid aspect, except during April

Fig. 19. Puawaina from Punahoù (⟵ East).

and May, when the rains water the scanty crop of grass which covers the whole hill with an evanescent mantle of green. The summit is about five hundred feet above the sea,[1] and as its substance is harder and more closely bound by the roots of the grass and shrubs on its surface, it has suffered less than Leáhi, still an examination of its southern edge shows that less than one half of its pristine size remains. In Dixon's "Voyage Around the World," a view of the cone is given, presenting high peaks; this was in 1786, and the natives declare that "many ages since, it had such a form."

The crater at the top is very shallow and covered with green sward. Its diameter is about six hundred yards, and it is of the usual oval form. The tufa is beautifully laminated, and well exhibits the double dip of about thirty degrees on each side of the rim. Lime encrusts the tufa on the south side, and seams of the same white substance occur in such abundance as to give the outer slope in many places a whitewashed appearance.

Near the little battery on the summit, is a rough pile of cellular lava and scoriæ which

[1] Found by President Alexander to be 460 feet.

seems to have risen to its present height, and, prevented by the superincumbent tufa, remains in the branched and ragged form in which it cooled. At the eastern side is a deep break, and another mass of dark basalt of slightly columnar structure. From the appearance of this side it is by no means evident that this break is coeval with the eruption which marked the formation of the cone; during the rains water collects in the crater, and a stream of some size rushes over the cliff, carrying with it a large quantity of earth and stones, and this agent has enlarged if not originated the ravine whose former contents are spread in a thick layer over the plain east of Honolulu. Two dykes are seen on this side, the one two, and the other ten feet wide. The basalt of these, as of all the masses visible in this cone, contains some chrysolite and minute grains of augite. On the northern side a conglomerate occurs, seemingly due to the ejection of scoriæ from the crater. In several places near the base, masses of rock occur imbedded in the tufa, the latter being raised around them precisely as a thick mud would rise around a heavy body dropped into it.

Near Punahoù at the entrance of Manóa Valley, are marks of another crater, and beyond this is much fresh looking basalt. Some disturbance seems to have caused the appearance of the spring which gives the name to the land of Punahoù (*New Spring*), and which evidently flows over extensive lime deposits, probably coral beds, the water being very hard.

Aliapaakaì Group. Six miles west of Honolulu, and three quarters of a mile from the sea, is a region of tufa craters of considerable interest, extending over ten square miles, and bearing marks of greater antiquity than any other similar formation on Oáhu. Several vents have coalesced, or rather the ejections of several have commingled as in the Kóko region, forming confluent arcs enclosing a plain almost a mile and three quarters in diameter and nearly level. The bounding walls are low, being on the northern side two hundred, and on the south not more than fifty feet high. They are formed of layers of tufa of a red color, more granular than that of Leáhi, but arranged in the same way. The *inner* slope and a portion of the outer have disappeared from the Aliapaakaì craters, while at Leáhi the *outer* has suffered most. In the tufa large masses of agglomerated chrysolite (*olivine*) are found, often four or five inches in diameter, also augite in dark green crystals, black mica, and garnets. Salt impregnates the whole mass of the inner walls, and is found in places on the cliffs where it could hardly have been brought by human hands. A large portion of the plain is occupied by the salt lake which gives the place its name (*Aliapaakaì*). In the rainy season large quantities of water rush in from the mountains through a hole near the centre of the basin, often bubbling above the surface, and extending the lake to the borders of the plain. At such times the water is about three feet deep, clear and dense, and intensely salt. The bottom is covered with a blue clay-like mud several inches deep, and is smooth and nearly level. During the dry season when the supply of fresh water is cut off, and the evaporation is very great, the lake is contracted to a third of its former extent, the water becomes oily and burning to the skin, the whole bottom is encrusted with large cubical crystals of salt, and along the shore the cakes of salt are sufficiently solid to bear the weight of a horse

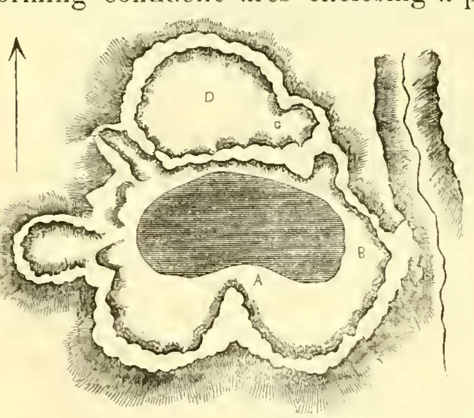


Fig. 20. Plan of Aliapaakaì.
A, raised coral reef; B, spring of fresh water; C, small crater; D, large crater, generally dry.

and his rider without cracking. The salt covering the bottom is much fissured, and it is on the edge of these cracks that the finest crystals occur. Large nodules, composed of brilliant cubes more than a third of an inch in diameter, are quite common in the water, and usually contain no nucleus. The salt is quite pure, and large quantities have been taken away for sale.

On the shore towards the mountains (B) fresh water oozes in through the remains of abandoned kalo patches, but the cattle have so trodden the miry soil that it is difficult to trace any stream. It is not possible that this lake has any communication with the ocean, as the tides rise and fall nearly two feet on the adjacent shore, a change of level sufficient to alternately drain and fill the shallow basin; and a rise of an inch would cause an advance in the shore line of at least a foot, while the most careful observations have failed to perceive any change which could not be attributed to the varying winds.

On the southern ridge near its base is a raised coral reef (A) much cracked and displaced, and fragments of coral are imbedded in the tufa of the walls on every side. Towards Éwa on the west is a hollow (D) which during the severe rains of the winter, contains a muddy pool of brackish water; this is separated from the salt lake by a narrow ridge, and is of similar formation.

Laelóa Group.

At Laelóa, the south-western point of Oáhu, is a cluster of small cones, distinctly visible from Honolulu, which bear marks of comparatively recent origin. All these have craters, and in two of them the rock projects in rude columns. They are mostly composed of a tolerably compact black lava, and are surrounded by lava of a red color broken into large loose blocks from two to twenty cubic feet in size, precisely resembling the masses so common near Leáhi. The highest of these cones is but three hundred feet above the sea, and, although from a distance conspicuous from its regular conical form, is hardly larger than some of the lava bubbles on Hawaii.

MÁUI GROUP.

(See Map, Plate XIII.)

The third division of the Hawaiian Islands consists of a group of islands of considerable extent. Máui, the largest, is next to Hawaii in size as well as in height, and contains the largest known crater. Molokaì, Lanai, Kahooláwe, and Molokíni are small, seldom visited by travellers, and have never been thoroughly explored.

Although closely clustered, and forming, as it were, the fragments of a former island of semicircular form, the members of this group exhibit some remarkable differences, both in form and constitution. Máui contains a lava which has never been found on Kauaì or Oáhu, while Molokaì abounds in a light gray stone, which is not known to occur anywhere else. Máui and Molokaì are islands of double summits like Oáhu, while Lanai and Kahooláwe are single, and resemble Niihau. The distribution of land-shells and of plants is also various, each island having several peculiar species. Whether they ever composed one island, or what their true relation to each other may be, will be examined further on; at present it remains to examine their physical and geological characteristics as separate islands.

Fig. 21. View of the Southern Islands from Molokai.

Máui. Molokìni. Hawaii. Kahooláwe. Lanai.

MÁUI.

Máui is a double island consisting of two peaks connected by a low isthmus, and its plan somewhat resembles the human bust, the head being towards the north-west. Its greatest length is fifty-four miles, breadth, twenty-five, and its area is six hundred and fifty square miles. East Máui is the larger, and is a mountain dome rising more than ten thousand feet above the sea. Háleakala (*the house that the sun built*) is quite regular in its slopes, which vary from eight to ten degrees, being somewhat steeper on the windward side. The lava beds of which it is composed vary much from those of Kauaì or Oáhu, being of a lighter color, less cellular, and more impervious to water. This is particularly the case with the lower beds where exposed by the ravines; and the beds of the streams are much worn into pot-holes, which serve as reservoirs during the part of the year when the stream ceases to run. On the surface the rock is more red and broken, closely resembling that near Leáhi on Oáhu. Lateral cones abound, some near the base, although on the northern side they seem very ancient, and no streams of lava have been traced from them. On the western side, near Ulupalakúa, several distinct streams of very fresh looking lava are found near the coast. All the windward side of Háleakala is much cut up by ravines, rendering travelling in the district of Hána laborious, and when the streams are high, even dangerous. The road winds up and down precipices over which the wind rushes with such violence as to sometimes oblige the traveller to dismount and seek shelter against the cliff on one side to avoid being dashed over the precipice on the other. Travellers among the Alps see less wildness of mountain scenery than the Hawaiian who rides from Hána to Lahaìna. On no part of the islands are the roads so dangerous, yet such is the skill of the riders, or the sure-footedness of the horses, that accidents seldom occur. Water is abundant in all the gorges, especially after a rain on the mountain, and the ridges are generally well wooded.

On the north-west side the path to the summit passes over a bare tract of land, destitute of trees save a few straggling koa or sandal-wood bushes, but covered with wild sage (*Sphacele hastata*), ohelos (*Vaccinium reticulatum*) and grass. In September 1864, the grass was thin and dry but extended to the highest point, as did a common *Sonchus*. The ascent was gradual and far more even than that of Mauna Lòa; indeed, a carriage-road might be built to the top with very little difficulty, the slope being much more regular than that of Mt. Washington in New Hampshire.

The immense size of the terminal crater does not at first strike one; but a brief examination of the cliffs which stretch their black precipices for a circuit of thirty miles, enclosing

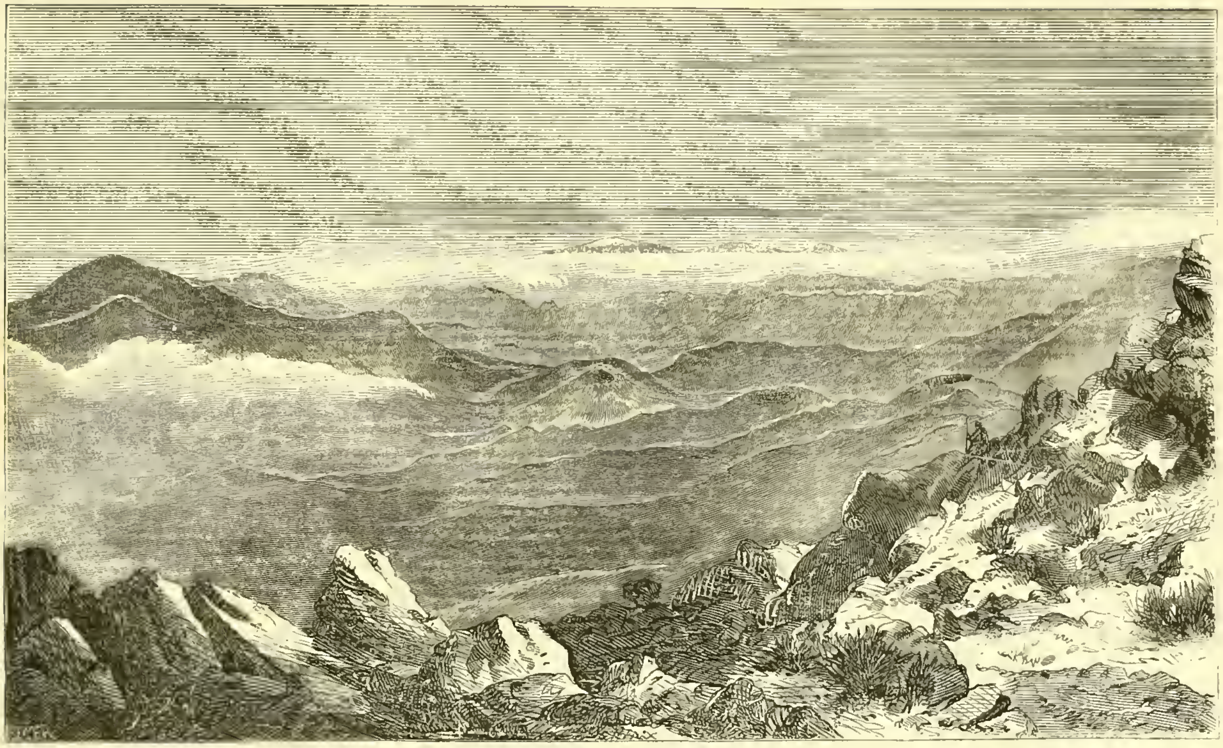


Fig. 22. The Crater of Háleakala, from a Photograph by Weed Bros.

several hills which seem from the top like mole-hills, but in reality are five or six hundred feet high, springing from a base eighteen hundred feet below the upper wall, — a glance at the small white specks which move along the cliffs at the beholder's feet, — and the full wonder of the place is recognized. It is not like the solemn grandeur of Mokuawéowéo on Mauna Lòa, nor like the black terrors of Kilauéa, but it is still a scene of desolation, and a mighty monument of the forces with which God builds the world.

Although the walls are steep, it is possible to descend almost anywhere, the sand or cinders having accumulated about the base of the rock cliffs. On the north and east are two vast breaks from one to three miles wide, as deep as the crater, and extending to the sea. Through these gateways two streams of lava found their way out, when, no one can say, although native tradition would leave us to infer that it took place since the Hawaiians came to these islands two thousand (?) years ago. Their appearance is in many places as fresh as the streams of 1801 on Hualalaì.

The eastern or Hána break is completely floored with the hard lava stream and occasional clinker beds, and for more than three miles from the crater a line of small cones extends along the centre. About half way down the mountain, this flow emerges from its gorge and spreads over the slopes to the southward in the form of a huge delta. It has blocked up several ravines, showing its comparatively recent origin. The northern or Koolaù break is quite similar in its formation, and extends directly to the sea. Both streams doubtless belonged to the same eruption. The bottom of the crater is dotted with sixteen large cones of regular shape, the acute end of their oval base being towards the north-east.

They are composed of cinders and scoriæ, generally of light specific gravity and reddish tinge, sometimes black, and again colored with the hydrated oxide of iron, as if steam had acted upon them while highly heated.

On these cones we find the first appearance of sulphur. Kauaì and Oáhu were free from it, and it is here in small quantities, much weathered, and quite impure; with this exception Hawaii is the only island where this common volcanic product is found. There is no steam or vapor, and not even a hot spring to mark the forces once so active in this mountain. A pool of cool and sweet water on the floor of the crater is carefully protected with stones.

This crater has never been surveyed, and the size is estimated by Mr. Drayton, of the United States Exploring Expedition, to be from one to two thousand feet deep, and fifteen miles in circuit. This is, however, much below the true circumference, which is nearer thirty miles. The highest point of Háleakala was determined by barometer to be ten thousand two hundred and seventeen (10,217) feet above the sea.

Fig. 23. Plan of Háleakala.

Caves are of frequent occurrence near the top, and have every appearance of lava bubbles. The rock of the crater is a hard gray clinkstone, much fissured, and in many places resembling artificial walls of cubical stone blocks; lower down the mountain the rock is softer and of a bluish tinge. A variety of feldspar, which Prof. Dana named Mauilite, occurs in the loose sand of the cones.

Háleakala has been long extinct. No warm springs or steam-jets, no mineral springs nor solfataras exist on Máui. Earthquakes are not more frequent, nor are there indeed any signs to indicate that it will ever shake off its slumber of two thousand years, and again pour forth lava. The slopes of Hána are as old to all appearance as those of Kauaì, and the soil is as deep and as productive.

Old as is East Máui, West Máui is older still, as is shown by its more broken surface, deeper soil, and extensive degradation. Its summit, Eéka, is six thousand one hundred and thirty (6130) feet high. No single terminal crater exists, although there seem to be the remains of several: the valley behind Lahaìna being one, and Wailùku Valley perhaps another. On a clear day, when the trade-wind clouds that usually hang over Eéka pass away, the clustered peaks as seen from Ulupalakúa more closely resemble the walls of a central terminal crater than when examined from a nearer point. Indeed, no one who had only seen this distant view would hesitate to declare that a crater of considerable size and distinct outline crowned the mountain.

Several of the valleys of Eéka have much the appearance of rents like the vast breaks in Háleakala. The valley of Io, near Wailùku on the south-eastern slope, is deep and wild; several curious pinnacles or needles have been formed by the degradation of the very sharp, thin ridges. The head of the valley forms an amphitheatre half a mile in diameter, and is raised above the level of the valley-slope by a terrace nearly a hundred feet high. It is not impossible that this was once a crater, and the lower part of the valley where the high and nearly perpendicular walls closely approach each other, was a rent which the waters and decomposition of the lava have enlarged. In no valley on the islands are the ridges so sharp as here; they often seem mere laminæ set up on edge, — almost the leaves of this vast volume of Nature.

Near Haikù on East Máui the soil is deep and productive. Many acres are covered with kukui-trees of large size, and on the cultivated ground sugar-cane yields good crops. Several of the broken-down tufa-cones produce good crops of cane, and as the rain-fall is frequent, the absence of all permanent streams is to some degree compensated. The shore is a cliff nearly perpendicular, washed by the surf. Where the rain-streams have broken through at Maliko, the section is as represented in the margin. There are three distinct layers, each twenty or thirty feet thick, of tufaceous lava, the top of each layer being burned red by the stream above it, and rendered prismatic for nearly a foot in depth, indicating great and uniform heat, as each stream is similar to the preceding one both in size and composition. The lower portion of each stratum is composed of loose rounded masses that are gradually forming a conglomerate. To the west of Haikù is a large tract of land of many hundred acres, formed by the wash of Háleakala, and capable of producing a large amount of cane, but wholly destitute of water. Should enterprise and capital ever unite in building an aqueduct from the streams of Hána to this dry plain, few places on the Hawaiian Islands would produce larger crops. Further up the mountain at Haliimaìla the rain-fall is sufficient to water large fields of cane.

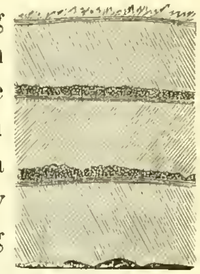


Fig. 24. Section of a cliff at Maliko.

On the western slope the soil is light, and at Ulupalakúa the dust in dry seasons is often a foot deep. Cane grows well here, although from the great elevation of the arable land, four years are sometimes required to ripen it. Below Ulupalakúa is the most recent lava-flow on Máui. Large fields of a-a, as fresh as if ejected but yesterday, line the coast for nearly a mile, while tufa-cones, some of considerable size, abound, indicating this as a line of extensive eruption; and it seems highly probable that Molokìni belongs to this series.

The low plain which connects East and West Máui is but a few feet above the sea, and several vessels have sailed upon the land not doubting the existence of a passage. On the windward shore the coral-sand is piled up in ridges nearly a hundred feet above the sea; shifting with the wind which sometimes drives columns of sand miles along the beach. As on Kauaì the large proportion of lime contained in this coral-sand, has a tendency to form a concrete; and perpendicular rods, often a foot in length and several inches in diameter, are found on the slopes of the more permanent hills near Wailùku.

KAHOOLÁWE.

Kahoolávwe is twelve miles long and about four broad, with an area of about forty square miles, and its elevation is nearly six hundred feet above the sea. The surface is comparatively level, not broken by ravines, owing to its slight elevation and its situation on the lee of East Máui. It possesses no streams nor fresh water, except in several pools of small extent. Grass and a few euphorbiaceous plants constitute the entire vegetation, and afford pasturage for a large flock of sheep. It is said that a crater exists on the summit, and that the strata have a slight dip from the centre of the island; but an examination from a vessel at a distance of a mile seemed to show a dip from the cliffs on the leeward side of the island, which are two hundred feet high, towards the centre. These high, and nearly perpendicular cliffs are highest on the south-west side, but extend nearly around the island, leaving few landing-places.

LANAI.

Lanai is eighteen miles north of west of Kahooláwe and but eight miles from the south-west shores of Máui. Its length is twenty miles, breadth eight, and its area about one hundred and fifty square miles. It is much higher at the south-eastern end where a mountain rises to a height of nearly two thousand feet, sloping gradually to the north-west, where its dry, almost barren declivities, terminate in a cliff a hundred feet high. On the leeward side the shore is a steep rock-wall three or four hundred feet high, exhibiting thick strata dipping from the centre of the island, while on the opposite side the mountain slopes nearly to the sea.

Fig. 25. Lanai from Molokaì.

Many valleys intersect the south-eastern end, and one of them is doubtless the remains of an ancient crater. There are no streams on the island, and it is difficult to account for the formation of the valleys on the supposition that they are wholly the result of wearing waters. While these valleys radiate from the highest point, which is near the south-eastern end of Lanai, the opposite end has hardly a gully, and presents an unbroken surface of gentle inclination towards the sea. The soil is red and the vegetation appears stunted.

Kahooláwe and Lanai are the only two islands that present high cliffs to the lee shore, and gentle slopes to the windward. On all the other islands the reverse is the case, and the rocky barriers are placed as it were to oppose the surf driven in by the prevailing winds.

MOLOKAÌ.

Molokaì is about nine miles distant both from Máui and Lanai. It is a long and narrow island, and closely resembles the eastern mountain-range of Oáhu. Its length is thirty-five miles, its breadth averages seven, and its area two hundred and twenty square miles. It presents from the north the appearance of a wall with ragged edge and varying height, rising nearly perpendicularly from a narrow level plain, and cut towards the western end,

Fig. 26. Molokaì from the North, distant fifteen miles.

where its height is least, by a low isthmus like that of Máui. The eastern end is far the higher, and Mauna Olokùi attains an elevation of nearly three thousand feet, while the western portion is a mere hill of about a fifth of that height.

Kaluaáha is the principal landing on the southern coast, and the mountain rises directly back of this, leaving but a narrow strip of cultivable land, except in the mountain valleys. The slopes are generally steeper than those of Eastern Oáhu, and are covered with grass and small shrubs to the top, while in the valleys and ravines trees of large size are found. From Kaunakakaì, seven miles west of Kaluaáha, the ascent is quite easy on horseback, although the surface is much broken by ravines. The soil is stony and of little depth, owing to the comparative infrequency of rain on the leeward side; but on the summit, where the trade-wind clouds settle, there is abundant moisture, and the trees and shrubs form a thick jungle in the numerous depressions. Olokùi is not flat like Mauna Lòa nor so narrow as Konahuanùi, but is exceedingly uneven on the top, and abounds in large irregular depressions between the summit peaks. Whether these are the remains of craters it is difficult to determine, they are so completely overgrown with a dense jungle. It is said that near the eastern end there is a large crater, but none of the inhabitants seem to possess any definite information regarding it.

The rock of the mountain summit much resembles hardened blue clay, and is of light specific gravity compared to the lavas of the side, and base. It is porous and splits to pieces with loud detonations when exposed to fire.[1] On the north the mountain ends in a high wall extending nearly its whole length, with a rough barren plain at its base containing many craters and lava bubbles: one of the craters is filled with sea-water and is quite deep. The appearance of this plain of Koolaupápa from the sea, is of a region flooded with lava-streams of a more recent date than any others on Molokaì, and these streams have issued from the small craters on the plain or from the very base of the precipice. There are but few places on the northern side where valleys afford the natives an opportunity of raising kalo and potatoes, and much of their food is brought from the eastern end. The low western point is white and sandy, and quite barren. Eastward of Kaluaáha the scenery is beautiful and romantic. Deep, narrow valleys open towards the coast, and often contain plantations of oranges and bread-fruit. The head of these valleys is frequently a perpendicular precipice, before which the gorge divides and smaller ravines open to the right and left. Mapuléhu is the largest, and is subject to torrents of water after severe southerly storms. The sides are very steep, and the stones at the bottom are much worn. Moanùi Valley contains several large caves in the side ridges, in one of which, now quite concealed, the ancient kings of Molokaì were buried. The eastern end of the island is a high bluff of smooth grass-land, and at the extremity the fine valley of Halàwa cuts through the strata for five hundred feet in depth, exposing a series of thin, almost horizontal layers of ochreous earth. The slope to the mountain from this place is less than ten degrees, while on the south it is nearly fifteen.

HAWAII.

The last and largest of the Hawaiian group is Hawaii itself. All the other islands exhibit only the effects of the volcanoes of ancient times, long since extinct; even sulphur-beds, solfataras, or hot-springs, which so often mark the expiring efforts of internal heat, are not found, nor does tradition notice their existence. The other members of the group are interesting, from the traces of former volcanic action, and for the effects of time on the igneous

[1] The author was obliged to remove a camp-fire which had been built on this rock, as the fragments were thrown several feet by the explosion.

products which they exhibit in such variety, but the geologist must look to Hawaii for the explanation of much that he sees on Kauaì, Oáhu, or Máui; and here better than at any other known place on the globe may the phenomena of an active volcano be studied. On Hawaii is the largest active crater in the world, and the whole island presents, in an accessible form. models and specimens of the work which has constructed the whole group. At all times the explorer may see the melted lava boiling and surging in its ragged caldron; he may approach it with an impunity which is marvellous in view of the mighty forces at work; and during the occasional eruption, may stand by the side, nay, even on the surface of a resistless torrent of melted rock often several miles in breadth, and flowing on for months in undiminished volume. Probably in no other place can the volcanic work be better examined than here, where for thousands of years — how many thousand who shall say? — fiery floods have poured forth, and still pour forth, until they have builded mountains of vast extent. All conditions of the lava-rock are seen here: basaltic and trachytic, solid and cellular, from the rich black soil, deep and fertile as on Kauaì, to the smooth hard rock of this year's flow.

To obtain the best idea of Hawaii it may be well to make the circuit of the island near the coast, to ascend the mountains, and finally examine the great volcano Kilauéa.

The form of Hawaii, as will be seen on the map, is roughly triangular, the western coast being eighty-five geographical miles in length, the south-eastern sixty-five, and the north-eastern seventy-five miles; the area is three thousand eight hundred square miles. Its whole surface pertains to the slopes of its four mountain summits,—Mauna Kéa on the north, which rises 13,950 feet above half-tide; Mauna Lòa on the south, 13,760 feet high; Mauna Hualalaì on the west, 8,500 feet high; and Mauna Koháľa on the north-west, about 5000 feet: — and so distinct are these summits, that a subsidence of six thousand feet would leave three islands, two of which would be eight thousand feet high, and the third would still equal the heights of Molokaì. From the sea on the east side the two mountains, Kéa and Lòa, are alone visible, and so slight is their elevation compared with their great horizontal extent that the voyager is wholly deceived in estimating their height. Their surface seems smooth and unbroken, their slope so gentle as hardly to be perceptible, and their rounded summits seem easy of access.

Starting from the western coast at Keálakeakùa Bay — the memorable scene of Cook's punishment — the island may be described as the traveller journeys along the coast towards the south and east. Keálakeakùa presents several points of interest. At the head of the bay is a nearly perpendicular rock-wall eight hundred feet high, on either side of which recent lava-streams have descended. The face of the cliff is broken in several places by large caves, and seems to be the section of a lava flow of great size, of which the extremity has been engulfed in the sea by some violent shock. The northern point on which Cook was killed is a lava-stream, and the bare black rocks on which he landed are part of a flow which may be traced up the steep ascent, and over the precipice in a black rock-fall, where every wave and curve and twist of the once molten torrent has been transformed into an iron-like mass, as if instantaneously. It is a remarkable fact that this cliff is the only similar one on this coast, while further south they are of frequent occurrence. Although they have not been tracked to the vent from which they issued, it is probable that the Keálakeakùa streams originate from Mauna Lòa, not from the nearer Hualalaì.

From the top of the cliff, the slope towards the interior is more gentle, and is covered with a deep and productive soil. Thick forests extend more than six miles up the sides of the mountain, and although no streams are found on the surface, the soil is moist and in many places even swampy from the frequent rains. Where the forests have been cleared away, oranges grow well, and the Kóna coffee is quite equal to the Mocha or Wynaad. The soil is full of small fragments of the spongy lava called *a-a*, which keeps it loose, and at the same time retains moisture in its pores. The red clayey earth, so common on northern Oàhu, is rare here, as the vegetation has converted the red and brown iron oxides into organic salts. The climate of Kóna is one of the finest in the world; the thermometer ranges annually from 60°–80° Fahr.; the nights are always cool with the mountain breezes, while the fresh sea-breeze during the day tempers the heat of a tropical sun, and while cooling the atmosphere for man, yet permits the luxuriant growth of bread-fruit and pines side by side with Indian-corn and apples.

Descending to the coast on the southern side of the bay, the steep, winding path leads under bread-fruit and kukùi trees, while the pandanus, and caricas (*Papaya vulgaris*), covered with yams and a beautiful convolvulus, clothe the slopes. On the shore, all is changed. A bare sand-beach, and black lava-rocks take the place of the luxuriant vegetation of the cliffs above, and only the cocoa-nut trees seem to flourish. Two miles to the south is a recent lava-stream a milé broad, which has passed through a grove of these palms, and the impressions of the fallen stems are stamped in the smooth lavas with wonderful clearness, the depth of the cast being often more than a third of the diameter of the stem; and it was easy to distinguish the casts of several fan-palms among the cocoa-nuts. The trees generally fell towards the advancing stream, sometimes in the opposite direction, and always left a deep round hole to mark their former position. By measuring the depth of these holes, the depth of the stream at this place was found to be between three and four feet, which would make its approximate bulk, from its source some thirty miles distant, nearly four hundred million cubic yards of rock! The surface of this, as of all other Hawaiian streams, presents three aspects: the *pahoehoe* or velvety lava, which is folded and twisted, in the manner of a viscid fluid, and may be compared to the homely illustration of a thick coat of cream drawn towards one edge of the milk-pan; the *clinkers*, or scoriaceous lava, rough and covered with fragments; and the *a-a* or spongy lava, a form of which no description can convey an idea of the horrible roughness and hardness. The pahoehoe is the most common form, and occurs when the flow passes over rocks or dry earth at a gentle slope, although the inclination may be more than 50° without the formation of scoriæ if the ground be tolerably even and the current unimpeded. The scoriaceous lava or clinker fields are found wherever the stream passes through woods, wherever its course is impeded by obstacles or inequalities in the ground, or where the heat of the melted rock causes the explosion of caverns in the former flows over which it passes. The a-a is the most puzzling to one who has never seen the actual process of formation, but it seems to occur when the lava meets with an impediment, which gives way just as the lava is granulated, rolling the spongy mass over, and building up huge piles from which the still liquid lava drains away.

The shore where this flow reached the sea exhibits no signs of a violent encounter of fire with water, but the lava has run into the sea with scarcely a break and may be seen beneath the water for several rods where it projects above the white coral sands which cover the larger portion.

Beyond this the shore is wholly black lava-rock, which often rises in cliffs from fifty to a hundred feet high, rough and jagged, full of rents and caverns, through which the sea rushes with great violence during a storm, leaping in vast white columns upon the shore above. Islets of every form have been broken off from the cliff, and form with their black rugged sides towering above the white surf a beautifully picturesque scene, which claims the admiration of the passer-by. Vast bubbles have broken down, opening large caves, and the whole surface of the rock is very uneven and broken.

At Kaulanamàuna the road leaves the coast and ascends a rather steep hill to the wooded region. Near Manukà a region of a-a commences, extending for many miles. No soil is found here, yet the traveller passes through forests of ohia-ha (*Metrosideros polymorpha*) where the trees average twelve inches in diameter, and sometimes exceed twenty, growing in the loose a-a, which forms a layer of unknown depth. It would seem unreasonable to select a pile of the slag from a blast furnace as a spot for potato raising, yet the Hawaiian makes a hole in the a-a, which looks quite like furnace refuse, plants a banana shoot, filling the hole with stones around the tender plant, and in ten months he gathers the fruit. Or he buries a sweet-potato cutting in the stones, covering the place with fern-leaves as a mulching, and in due time digs, it may be, a bushel of large fine potatoes. Awa (*Macro-piper methysticum*) grows well, and since the removal of all prohibitions against its culture, has been extensively planted. Beyond this ancient a-a, a more recent flow of the same material covers an extent of six miles, and its ridges, although scantily covered with vegetation, present a horrible scene of roughness and desolation. Piles of a-a fifty feet high, rents in the more solid pahoehoe beneath it, make the path uneven and tedious. The road is built with care, and where worn is good, but the fresh a-a, with which the bed is repaired, is as hard as glass, and although the iron shoes of the horses grind it down, the bare feet of the natives, or even the leathern soles of the foreigner, suffer exceedingly. Next this rough region which extends over nearly sixty square miles, a tract of pahoehoe stretches from the mountain to the shore, so hard that no tracks are worn by the horses, and it would be difficult to mark the road were it not for piles of stones erected for the purpose. This extends a mile, and is succeeded by a green grassy ridge of totally different character from any yet met with on Hawaii, and much resembling the rocky uplands of New England. This ridge of Kahúku seems to proceed from the upper mountain regions, with a slope of less than eight degrees, to the sea, where it terminates in a steep bluff surrounded by cone-craters of red earth. None of these cones are very large, and their sides are steeper than those of Oáhu, resembling in outline cinder-cones rather than tufa, not being much furrowed or broken down. The grass-land extends five miles, and is then interrupted by the large valley of Waiohínu, where is the only running stream on this side of the island for a hundred miles. This brook rises from several springs not many miles up the mountain, and is clear, cold and never-failing, although small in volume. The Waiohínu Valley contains the principal settlement and the mission-station of the district of Ka-ù ; it is very fertile, and many fruit-trees of temperate regions grow here with wonderful rapidity.[1] No valleys have been met before, but beyond for fifteen miles the country is broken with ridges and valleys, the former broader and rounder, and the latter smaller and shallower than those of Oáhu or Máui. The soil is seldom more than a foot deep, but is productive, and the district seems to have been long exempt from the lava-streams from the mountain above. The explanation of this seems to be, that this part of the island was in ancient time by some great convulsion broken

1 The writer has seen in the garden of Mr. Spencer a peach-tree which had attained a height of ten feet, and was wide spreading, six months from the time it sprung from the stone.

from the mountain-side precisely as the portion between the breaks of Háleakala on Máui, the lava flowing on either side of the wedge-shaped fragment. In support of this view a valley running transversely to the Ka-ù ridges may be cited, which bears evidence of disruption, and which has received and turned many streams of lava from the mountain above.

Near Punalúu, along the shore for four miles, the lava is hard pahoehoe intersected by a ridge of clinkers twenty feet high, three quarters of a mile wide, and at right angles to the shore, bearing marks of comparatively recent formation. From its relation to the smooth grassy hills above it, it would seem to have issued from the plain and not from the ridges. More than thirty lava-streams have been counted on this side of the island from Keálakeakùa to Punalúu, marked by slight differences of shade or decomposition.

Fifteen miles from Punalúu the fertile soil ceases, and pahoehoe takes its place. Trees still border the pathway, and in several places deposits of volcanic sand are found which are said to have been thrown out of Kilauéa in 1790. Here the road branches to Kilauéa, whose smoke is clearly seen. In this neighborhood in 1823, the Rev. William Ellis found what he considered a nascent volcano; deep rents and chasms, from which steam and smoke were issuing, and masses of fresh black lava, scattered on the scorched trees and bushes near by, gave evidence of recent if not continuing action, and the natives told him that the ground had fallen in and the lava was ejected in September 1822. The place is called Ponahohòa, and at present there are no signs of steam or smoke, although the lava looks fresh. It was probably in the track of a subterranean eruption from Mauna Lòa or Kilauéa.

Passing again to the shore down a steep declivity two thousand feet high, near a row of cones extending from Kilauéa to the coast, the road crosses what the natives call *pahoehoe lapalapa* — lava that looks like boiling water. It was formed by passing over caves in the older rock, exploding them and raising in this way bubbles and cones, as well as small tracts of a-a. It is very easy to see, even at a distance, where the a-a occurs, as there trees spring up, while the solid pahoehoe forbids the entrance of a root except along the cracks. The former is often covered with vegetation a few months after its ejection in regions where rain falls, but the pahoehoe may remain bare and fresh-looking for centuries.

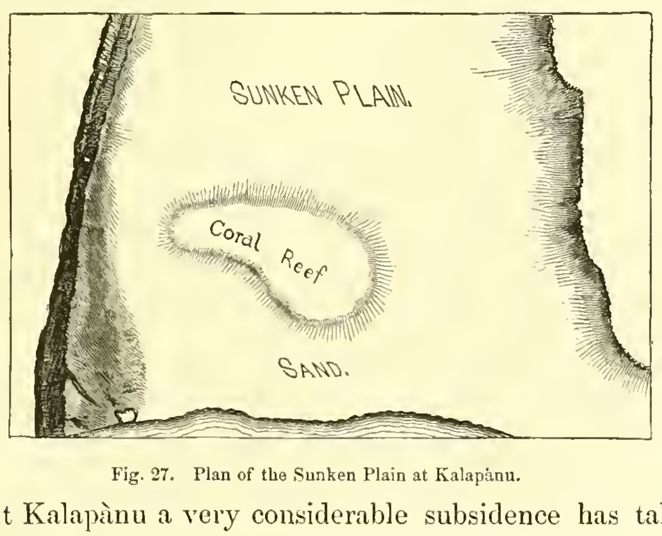


Fig. 27. Plan of the Sunken Plain at Kalapànu.

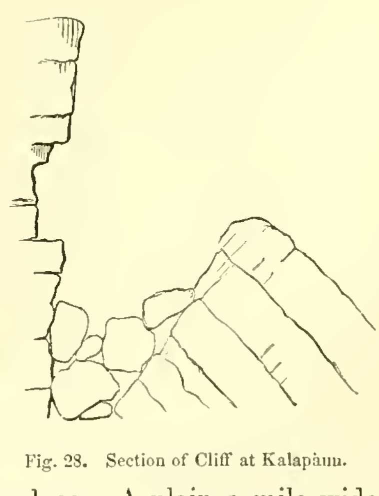


Fig. 28. Section of Cliff at Kalapànu.

At Kalapànu a very considerable subsidence has taken place. A plain a mile wide and two miles long has sunk nearly fifty feet, leaving the surface not more than two feet above high water. A precipice fifty feet high bounds this sunken area on the south, having a fosse at its base partly filled with blocks of lava.[1] A raised coral reef extends along the shore half a mile, forming an embankment against the sea, and would seem to indicate another change of level in more ancient times. The mountain meets the sea in a long, high ridge- and there is no marked break between this and the plain so far as examined. The lava, strata exposed in the wall near the shore are thin, seldom exceeding three feet, and of a compact dark basalt on the surface, while below phonolitic lava is the common kind. All the coast in the district of Púna is rocky, and destitute of landing-places, except near Kalapànu, where there is a sand-beach. Here the sea often beats with great violence on the loose volcanic sand, and the natives enjoy their remarkable pastime of riding on the surf. The sea is evidently advancing on the shore, as the stumps of cocoa-nuts are standing in the water half buried in the black sand which forms quite a steep slope above them. This place is interesting as exhibiting the effect of a heavy surf on volcanic cliffs and lava-beds where not protected by a fringing coral-reef. Prof. Dana seems to doubt that the ocean has played an important part in the formation of the bays of these islands, and adopts what is doubtless the general rule, that the sea tends to obliterate bays by the removal of projecting head-lands. Here is, however, an example of the excavation of a bay by the surf.

Near Kapóho are many cones, and they seem to extend in several nearly parallel lines towards the mountains. One group much broken down contains a pool of stagnant water about twenty feet deep and of a green color. Nothing remarkable was observed in its neighborhood, although the natives believe that its waters become yellow and then black during an eruption of Kilauéa. The water is not warmer than might be expected from its exposure to the sun, and is perfectly sweet. Another cone half a mile from this is about two hundred and fifty feet high, and crowned with an ancient *heiau* or temple, and a clump of cocoa-nut trees. This cone is largely composed of lava, and is doubtless of great age, as the soil upon it is several feet deep in some places. At its base is a large cleft in the rock some three hundred feet long and sixty wide, in which is a remarkably clear pool of warm water, twenty or thirty feet deep and of a temperature of 90°. The water is perfectly fresh and sweet to the taste, but owing probably to its temperature, the dark-colored bodies of the natives bathing in it seem almost white, and a white man resembles marble. The sound of water trickling down within the cliff is distinctly audible after a rain.

Three quarters of a mile from this is a deep narrow cavern into which one may climb, guided by the natives with their bambu torches. It is nearly fifty feet deep to a pool of very warm water which is said to extend more than half a mile under ground.[2] All along the shore for twenty miles, warm springs are common near low-water level. No mineral waters however are found here, nor is there anywhere on the Hawaiian Islands even a carbonated or sulphur spring. The ground is mostly covered with a-a through the whole district of Púna, and of course it cannot retain pools of water. All the rain which is not absorbed by the porous a-a, sinks at once to the sea-level and issues in the clefts on the shore. As there is hardly any soil, it might be supposed that Púna would be a barren region, but the reverse is the case. Groves of cocoa-nut trees extend for miles, growing more thriftily than any-

[1] This formation is quite similar to that of the valley of Thingvellir in Iceland, but unlike that sunken plain, Kalapànu has but one bounding gja or rift.

[2] The writer saw several natives swim nearly that distance holding their torches clear of the steaming water, and the indistinct view thus obtained of the cavern, led to the conclusion that it was a deep crack, over which a subsequent lava flow had formed a roof.

where else on the islands, and the natives have no difficulty in raising pines, bananas, and other fruits. The a-a is often so rough that horses unshod cannot stand on it out of the beaten road, without a carpet of pandanus leaves or sea-weed.

At Nanawálie the flow of 1840 crosses the road in a branching stream a mile wide, and rough with broken caves, clinkers, and a-a. The once high sand-hills of Nanawálie. thrown up where the lava entered the sea, have lost more than half their original height, worn away by the waves which encounter little resistance in the loosely agglomerated black sand of which the hills are composed. The a-a contains a large proportion of olivine, and large granules measuring a third of an inch in diameter are found on the shore. The road is six feet wide, built over the rough lava and covered with the black sand which forms a good bed, and is precisely similar to the sand found in layers near Honolulu and elsewhere on the islands.[1] It is an interesting fact that trees which were encircled by the lava of this flow are still alive, the stream having passed within thirty feet of them on either side. This would indicate an absence of carburetted or sulphuretted hydrogen, or other gases fatal to vegetable life.

The slopes of Kilauéa are quite regular in this district, and many eruptions have flowed down this way. At least twenty may be counted in thirty miles. Tradition declares that formerly Púna was a fertile region surpassing in the productiveness of its soil any district of Hawaii, and that during the absence of the chief of the district, Pélé, the goddess of the volcano, left her abode in Kilauéa to pay him a visit. From the appearance of the streams of lava it is not impossible that many of them were synchronous, and that the larger portion of Púna wàs overwhelmed by the same eruption of Kilauéa. None of the lavas of Mauna Lòa have ever flowed this way.

Leaving Púna the traveller also leaves the barren pahoehoe and the rough a-a, and enters the beautiful and fertile Hìlo. On the very borders he crosses the first stream of water he has seen since leaving Waiohínu. Fields of high velvety grass, the deep, dark foliage of the ohia-ai (*Eugenia Malaccensis*), the green and wooded slopes on the left and the broad ocean on the right, delight the eye, while before him the majestic, and it may be, snow-capped domes of Kéa and Lòa, every ridge, — almost every rock, — visible through the clear air; the little white village of Hìlo half buried in mango-trees and bananas; — all complete a view seldom equalled, which wholly effaces the weary thoughts of a hundred and fifty miles over roads which wear out the horses' feet and the riders' patience.

The people of Hìlo claim that their village is the most beautiful on the Hawaiian Islands, and few will dispute them. Almost daily showers cool the air, and refresh the rapidly springing vegetation, while the sea and mountain breezes remove all dampness,[2] and prevent the lassitude so commonly attendant upon a moist tropical climate.

The harbor of Waiakéa is, after that of Honolulu, the best on the islands. The town is built on the slopes of Mauna Lòa, which rise regularly with an average slope of 8°–10° to the summit. The soil is deep and loamy, and being well watered is exceedingly productive. Directly back of the town are three cones in line from the mountain towards the sea, about five hundred feet high and containing deep craters, one of which is filled with bambus.

[1] Similar black gravel is found among the tufa-cones near Victoria in Australia. See *Transactions of the Royal Society of Victoria*, vol. vii., p. 153.

[2] During a rain which continued several days, the writer was able to dry readily papers used in the preparation of botanical specimens, and the latter did not mould at all when exposed to the air in the open verandah.

The Wailùku, the largest river of Hawaii, empties into the sea at Hìlo. Its sources are on the south-eastern slopes of Mauna Kéa, and it forms the boundary between Kéa and Lòa. Occupying such a position, it has received the lavas of both mountains, and exhibits in its rocky bed many a record of conflicts between fire and water. One of these "writings on the wall" discloses the interesting fact that Kéa poured forth lava after the surface was sufficiently decomposed to retain the streams which supply the Wailùku. This is shown in several places, although it may still be one and the same stream, and it must not be inferred that the stream of water which produced the effect on the melted lava was a temporary flood from the snows melted by the eruption. When the snows melt on Mauna Lòa no stream from them reaches the base of the mountain, but the water sinks at once into the porous rock where the snows lie, and to supply the bed of the Wailùku even temporarily, Mauna Kéa must have been subject to the decomposing forces of many ages, unless it be supposed that it was originally built of a more compact material, which certainly is not shown by any examination that has yet been made.[1]

The water has often flowed over heated beds of basalt, and the consequence has been the formation of columns radiating from the bottom of the stream. Often where falls occur, this columnar structure is beautifully exhibited as Gothic archways, from whose apex the torrent pours into a basin surrounded by these curved and broken, half-sunken prisms, black and prominent amid the white foam of the falls. Where the lava has poured into the water, deposits of black volcanic gravel are usually formed from the fracture of the lava, but such deposits are from their nature peculiarly liable to be removed by the action of the water, and it is only where the course of the stream has been changed that they are found *in situ*.

From the much worn condition of the lava over which the river flows it might be supposed that the rock was quite soft, but the great attrition is partly to be attributed to the harder fragments of dolerite brought down from the heights above by the freshets, which scrape and grind the bed of the stream to a great extent, and are themselves rounded when they reach the sea. Under the falls, which are sometimes a hundred feet or more in height, deep pools are worn, into which it is the delight of the Hawaiian youth to jump from the dizzy verge of the fall above.

The Anuenúe, or Rainbow Falls, are about a mile from the sea, and beneath the sheet of water which falls more than a hundred feet is seen another result of the sudden chilling of heated — not melted — basalt. The columns at the point of contact with the water are at right angles to the surface, but curve regularly below, and the surface is much harder than the lower portions, so that while quite perfect near the top where the wearing action of the water is considerable, they are completely washed away below, forming a cave of some depth beneath. It has been suggested that this and similar caves beneath water-falls were simply bubbles in the lava-stream, and that the curved prisms owe their origin to the more rapid cooling of such a cavity, even without the agency of water. But wherever columns of basalt occur around such bubbles, they are always at right angles to the surface of the bubble, that is, in a section, they form radii and not arcs, while in the three or four waterfalls examined they exhibited the structure represented in the diagram.

[1] No foreigner seems to have penetrated the ravines which intersect the northeastern slope of Mauna Kéa, so far as to examine the solid core of the mountain. As the summit presents no crater walls, we have only the surface overflows of lava to judge from. The exceedingly compact axe-stone, however, is found in several places near the summit of the mountain.

Fig. 29. Section behind a Fall on the Wailùku.

In several places the Wailùku has pierced the beds of lava, and in one place passes beneath a thick rock-bridge several hundred feet wide. Often where the water flows over beds of compact dark gray basalt, masses of trachyte closely resembling syenite, have formed pot-holes, and by mutual action have been worn to pebbles. A remarkable series of these pot-holes occurs some five miles up the river. These are three circular pools in a bed of columnar basalt, each about fifty feet in diameter, and separated by walls about six feet thick. During high water the river rises sometimes thirty feet and completely hides the pools, filling the ravine in which they occur, but during the low water in the dry season, the upper bed is bare, and after a succession of cascades of various heights the river pours into the first basin (A) from a height of thirty feet, filling it with foam. From this there is no visible outlet, but fern leaves thrown into it soon come out in the second near one side, where a few bubbles alone disturb the tranquillity of the clear deep pool. From this to the third there are two sub-

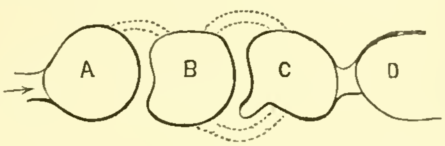


Fig. 30. Plan of Pot holes in the Wailùku.

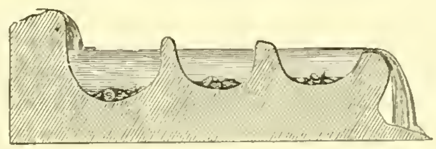


Fig. 31. Longitudinal section of Pot-holes.

terranean passages, one on each side, and the water escapes at last over a fall some forty feet high, nearly covering a perfect Gothic arch which forms the entrance to a shallow cave. The whole series is enclosed by high and almost perpendicular walls, not unlike those of Trenton Falls in New York.

In many places where recent lava-streams have flowed into the river and been broken up, the sand and chrysolite resulting have been washed to the sea, and are there thrown up in the clefts along shore, and such large deposits of the green sand are sometimes found, that it has been used in mortar to lay the furnaces and pans of a sugar-boiler — a purpose for which it seems well suited from its refractory nature. Quartz crystals have been found in masses of lava, but are mostly small, although clear and perfect.

The coast of Hawaii from Hìlo to Laupahòehoe, a distance of thirty miles, consists of a precipice from one to five hundred feet high, and extending to nearly the same depth beneath the water, so that in calm weather, large ships may approach close to the cliff. The road runs somewhat inland, and is one of the most remarkable in the world. Ravines, eighteen hundred or two thousand feet deep, and less than a mile wide, extending far up the slopes of Mauna Kéa, streams liable to sudden and tremendous freshets, must be traversed on a path of indescribable steepness, winding zigzag up and down the beautifully wooded slopes which are ornamented with cascades of every conceivable form. Few strangers, when they come to the worst precipices, dare to ride down, but such is the nature of the rough steps that a horse or mule will pass them with less difficulty than a man on foot who is unused to climbing. No less than eighty-five streams must be crossed in a distance of thirty miles.[1] The amount of water is great, and the soil is often so soft

[1] The following description of a passage over part of this road may convey a better idea of its rugged nature. It is taken from the author's journal: —

" During the night it rained hard, and we were told that the rivers would be impassable early in the morning, but that the water would rapidly subside. We waited until half-past eight, and then rode on, the Road Supervisor, Mr. R., having preceded us more than an hour. We crossed two or three small from the frequent rains as to be almost impassible, especially near Onomèa, where the soil is deep and fertile, of a yellow loamy nature. Were it not for the ravines, and the impossibility of transportation, many acres of sugar-cane might be cultivated. For twenty miles to Laupahòehoe there is no good landing-place, and during a storm the whole coast is inaccessible except to skilful natives in light canoes.

The strata, as exhibited in the ravines which have been excavated by water, are deep and similar to those described on Kauaì, and bear tokens of as great age. Denudation has been very extensive, and the water-worn valleys extend far up the mountain. The rock is generally a dark gray basalt, sometimes a light colored clink-stone, but scoriæ and a-a are very rare, owing to their more rapid conversion to soil where water is abundant, and not a single deposit was seen during three journeys through this district. Forests cover all the windward side of Mauna Kéa, and extend nearly around it in broken bands.

In Hamakúa the road branches, one continuing along the shore to the beautiful valleys of Waipìo and Waimànu, both of which belong to Mauna Kohála, and exhibit signs of great age; the other turns up the mountain side and soon enters the forest, culminating nearly five thousand feet above the sea on the north-west slopes of Mauna Kéa, and descends into the grassy plains of Waiméa. No streams are met for twenty miles, and the soil is much more scanty than where the rains fall on the other side. The view of Mauna Kéa from the

streams, and then came to one of three large rivers we had been warned against. As we descended the Pali, which makes Gen. Putnam's famous ride down the steps, child's play, we heard the rushing waters several hundred feet below us, and occasionally caught a glimpse of the white foam through the branches. When we at last came to the bank, we found the ford wide and cleared of stones, which above and below this place almost blocked the stream. The water only came half way up our stirrups, and we crossed in safety, rejoiced to have one of the dreadful Jordans behind us. When some two miles up and down almost perpendicular walls brought us to the second of the dangerous streams, our courage was up, and although the river was a hundred feet wide, and much resembling Niagara River in the rapids, I spurred my mule and plunged in. In an instant my poor beast was off his feet, and a native on the other bank screamed to me to go back, for I should be 'make' (dead) if I tried to cross. I of course obeyed, although with some difficulty, and found Mr. R. patiently waiting in the bushes a short distance up the stream where the water was deeper, but free from rocks. He told us that it would be useless to attempt to ford without natives and ropes, and as he had sent for both, we sat down to wait. In the course of an hour the river had fallen a foot, and two young Englishmen, who had passed the night at a neighboring plantation came up, and we were also joined by the United States Minister Resident who was making the tour of Hawaii. Our natives arrived, and the crossing commenced. First my mule was attached to the middle of a long rope, and a native swam across with one end, we retaining the other to prevent the animal from being carried down stream. Thus with great difficulty all the horses and mules were got safely across, and in the mean time a native had been swimming over with all our baggage. He swam with one arm out of water grasping his load, and got every thing over dry, even our heavy Mexican saddles.

"When the animals were all over, a rope was made fast on either bank, and the company stripped and swam, holding to the rope. As the current was very rapid, the swimmers often were whirled around the rope like a water-wheel, and as I did not like the operation, I had been making friends with an old but powerful Kanaka, who seemed to take a fancy to me, and who wished to carry me over on his back, a proposition I emphatically declined, but I made him understand that I would cross on the rocks below if he would go before to show me where to put my feet, as most of the rocks were covered two feet deep with foaming, rushing water. This he thought well, and, armed with a stout guava-stick, I stepped in. Down came the torrents from above, covering the ford more than twelve feet deep, and after rushing by me, almost shaking the great rocks some more extensive freshets had scattered across the channel, went thundering over a fall below, where it was lost in the dense foliage. So strong was the current that had I lost my balance there would have been but little chance for me. The rocks being usually far above water were not slippery, and when I once got a foothold, I was quite firm. I crossed safely, and as I had not taken off my clothes, was in my saddle before the rest of the party were dressed. They stood watching us as we jumped from rock to rock, with such interest, they said, that they forgot to dress!

"Another river was crossed in precisely the same manner, and we rode through many streams that came over our saddles. Mr. R. assures me that from Hilo to Laupahòehoe, a distance of thirty miles, there are eighty-five water-courses. I believe this to be literally true, and when I add that many ravines occur without streams, some idea of the broken nature of the country may be obtained. . . . The beauty of the scenery is wholly indescribable, and I believe nowhere in the world are collected in so small a territory, so many cascades of every form, of pure, clear, cool, mountain water."

I have since travelled over this road twice, and found no difficulty, owing to the dryness of the season.

road shows several of its terminal cones to great advantage, and they much resemble the lateral cones of Hualalaì.

The district of Waiméa is generally destitute of water, and the vegetation depends wholly on the dews and rain. Nevertheless as a grazing land, Waiméa is perhaps unequalled on the islands, although of late years the introduction of several foreign plants, of which the indigo and verbena are the most troublesome, has much diminished the grass. From its considerable elevation, the climate is cool and salubrious, and is much recommended as a sanitarium. Frosts sometimes occur, and the fruits and vegetables of temperate climes thrive well. Common American potatoes are raised here in large quantities, and in the early days of Californian immigration were exported to the coast.

Many lateral cones have been thrown up on the slopes of Mauna Kéa near Waiméa; and Mauna Kohála has also formed cones of a red ochreous earth covered with grass, and at first resembling tufa-cones, but they seem to be simply decomposed lava or scoriæ, as they do not exhibit the stratification of tufa-cones: those of Kéa are mostly scoriaceous and much furrowed, while these are not at all furrowed, owing to an early growth of grass. Some of them have shallow craters at the top, while others have no depression, but the soil is muddy or soft on the summit. Many large caves are found in the lava-streams which have flowed this way, and some of them, as on the other islands, have been used as sepulchres.[1]

The road from Waiméa to Kohála, the north-west district of Hawaii, crosses the western spur of Mauna Kohála at an elevation of about eighteen hundred feet, and traverses a region of cones, some of them quite perfect and five hundred feet high, while others are broken down. Lava streams have issued from some and flowed down to the coast, a distance of two or three miles. These cones much resemble the extinct craters of Auvergne in France.[2] Kohála is a fertile region, owing to the lengthened period during which its mountain has been in repose. The ridges are broader and smoother, covered with grass or canefields, and not rocky. The shore also becomes lower, and affords several good landing-places. Small streams are frequent, although the land cannot be considered well watered through all the district. Mauna Kohála has seldom been ascended, as its summit, although not high, is swampy like Waíaleale on Kauaì, and full of dangerous bog-holes. Its name is said to have been taken from *Kohala* (a whale), and it is not a single dome like the other mountains of Hawaii, but an elongated ridge like Konahuanùi on Oáhu. It is well wooded, and several trees grow there that are not found elsewhere on the islands, and some that grow only on Kauaì. It is quite remarkable that Waíaleale, Kaàla, and Kohála should be so swampy on their summits, while at their base, and on their slopes, the soil is often dry and barren. The three mountains are alike in other respects, in the absence of a single terminal crater, and terminal cones, and in the presence of crateriform marshes, and circular pools. They are probably all of the same age, as they have suffered an equal denudation, allowing for the different exposure to the trade-winds, and consequently to rain.

From Waiméa to Kawaihàe the ground is rocky, and dry. Pahoehoe, and broken beds of lava destitute of vegetation, cover many square miles; and the same is true of most of the

[1] The walls of these sepulchral caves are quite porous, and the air within is very dry, converting the bodies into dry mummies without further decomposition. A party which recently visited one of these caves found a body perfectly preserved, which had been dropped near the entrance, the bearers having probably been frightened away, as the two poles between which the body was slung were still attached.

[2] See Scrope's *Extinct Volcanos of Central France*

coast from Kawaihàe to Kailùa, a distance of fifteen miles, except where a few small streams make their way to the surface near the shore and furnish water for kalo-ponds. The natives live principally on fish, which are very abundant and good along the coast. The lava-flow of 1859 has flowed out some distance beneath the sea on the coral-reef, and the same is true of the flow of 1801 from Hualalaì which filled up a large fish-pond and extended the coast some distance. Beyond Kailùa the shore-plain is very narrow, and the sides of Hualalaì rise steeply for several hundred feet to a plain of rich soil forming a belt a mile wide in some places. Between Kailùa and Kaáwalòa the land is fertile and much cultivated, while high up the mountain are extensive forests of koa and ohia.

Having thus hastily sketched the general features of Hawaii along the shores, the mountains next claim attention, and in describing these the author's notes of ascents of Hualalaì and Lòa in 1864 will be chiefly used, while the accounts of several who have ascended Kéa in previous years, must be depended on for that mountain.

Fig. 32. Outline of Hualalaì from the plain on the south-east.

Hualalaì. — On Thursday afternoon, July 28, 1864, Mr. Horace Mann and myself, with a guide, left Kaáwalòa. Our way led at first through open pastures, then through tracts of tall ferns, and finally we came to the forest, where the soil was black and muddy, and the bushes so close as to almost prevent our passage in some places. Gigantic raspberries, with stems two inches in diameter at the base and twenty feet long, hung across our path and often scratched both ourselves and our horses in spite of our precautions. It rained hard, so that we were quite wet, and the clouds prevented our seeing much on either side. After some six miles of forest, we came upon a bed of a-a, fresh-looking and rough, and the trees were thinner and smaller. We were now on a dismal, foggy plain of pahoehoe and gravelly sand, where we could see but little out of our path. This was the elevated plain between the three mountains, and being at least four thousand feet above the sea the atmosphere was cold as well as damp.

A leguminous-tree (*Sophora chrysophylla*) called by the natives Mamáne, was common; the sandal-wood was seen here and there, but of small size, and the ohélo (*Vaccinium penduliflorum*) covered the ground thickly, and was loaded with its large red and purple berries. Twisted lava streams, and masses of scoriæ crossed our path, and so complicated were they that it was almost impossible to trace their course. About sunset we came to the place our guide had selected for our camp, and we soon had a fire at which we dried ourselves and roasted some sweet potatoes, and as the rain had ceased, slept comfortably under some bushes. Our water came from a curious pool in the last place one would think of looking for water, in the midst of a horribly rough bed of scoriæ, porous as pumice, and broken into irregular masses of all sizes. The basin holds about twelve gallons of cold, pure water, and has no evident inlet or outlet, yet is never exhausted; we nearly emptied it, and the next morning it was full again. It was found accidentally, and three columns of stone are piled up to mark the place, which would be most difficult to find without these signals.

At half-past five in the morning we started for the summit, toward which a good path led for some distance, and we galloped over the hard gravel beds, dodging in a zigzag course the clumps of bushes in our way. The morning was clear, and the birds which are scarce near the shore, were abundant, and sang merrily. The path ended after three miles, and we had to slowly pick our way over difficult and even dangerous lava-fields. Our horses occasionally broke through, causing some trepidation to the riders, but no accidents occurred; and after passing nearly round the summit, crossing the flow of 1801, and counting ten flows from the top, and many others almost indistinguishable, we reached the base of the highest plateau at eight o'clock, and left our horses in a little valley where strawberries were abundant, and also American potatoes, planted by some native.

A climb up a steep slope some three hundred feet high, and we were in the midst of a series of large pit craters extending over the whole summit. These craters were very much alike, from three to five hundred feet deep, and from seven hundred to a thousand feet in diameter. The walls were of the solid graystone, seldom capped by cellular basalt in beds, (although the lava was piled in scoriæ near by), and were nearly perpendicular. Vegetation extended to the bottom, and the beautiful Silver-sword (*Argyroxiphium Sandvicense*) was growing in the clefts far down the sides. The bottom was usually flat and gravelly, but in some cases covered with smooth black lava, and in others rough and broken. Fragments of the walls were often seen at their base, and in one crater they were half melted into the lava which covered the bottom, proving that the clinkstone of these mountain summits is fusible by the melted black basalt.

No signs of steam or sulphurous vapors were visible, but on the edge of one of the deepest craters, on the wall which separated it from another less than two hundred feet distant, was a mound of scoriæ some fifty feet high, composed of drops and slightly agglutinated fragments of lava of all sizes and colors, black, red, orange, blue, golden, apparently ejected in a viscid state, and in the centre of this a blow-hole about twenty-five feet in diameter, and, as nearly as we could judge by throwing stones, eighteen hundred feet deep to a ledge, to one side of which we could see a deeper black hole. I was obliged to lie flat on the edge to examine it, the scoriæ were so loose, and the whole cone jarred as we climbed over it. The inside of the blow-hole was of a brown color, smooth as if turned, and grooved horizontally. No vertical striæ could be distinguished, but as these horizontal grooves seem to correspond to the strata of the adjoining crater-walls, I suppose that the projecting ridges mark the more solid substance of these strata, which would be in their centre, while the scoriæ which separate the beds to some extent, would permit the deeper action of the vapors which have formed the hole. Mr. Mann suggests that the column of ascending vapors had a rotatory motion around a vertical axis, but in that case the grooves would be spiral and not circular, and the fragments of lava ejected would have struck the surface obliquely, unless thrown to such a height as to lose the original motion. The wearing force must have been chemical rather than mechanical, as the wall of the crater adjoining, which is not more than twenty-five or thirty feet thick, would have given way to any violent explosion. A similar blow-hole was described by Ellis lower down the mountain. He ascended Hualalaì in 1823, and found on the side of the mountain a large extinguished crater, about a mile in circumference and apparently four hundred feet deep. The sides were regularly sloped, and at the bottom was a small mound with an aperture in its top. By the side of this large crater, divided from it by a narrow ridge of volcanic rock, was another, fifty-six feet in circumference, from which volumes of sulphurous smoke and vapor continually ascended. No bottom could be seen, and on throwing stones into it they were heard to strike against its sides for eight seconds, but not to reach its bottom. There were two other apertures very near this, nine feet in diameter, and apparently two hundred feet deep.[1]

This description corresponds so nearly with the blow-hole we saw on the summit that it cannot be doubted that vapors formed, or at least enlarged, both.

From the vegetation of the summit I should not consider Hualalaì more than 8500 feet high, although some have placed it as high as 10,000.[2] It is covered with lateral cones, and its summit is flat, with many large pit craters. More than one hundred and fifty lateral cones have been counted, and it will be seen from the outline of the mountain (Fig. 32) that they vary much in shape and size.

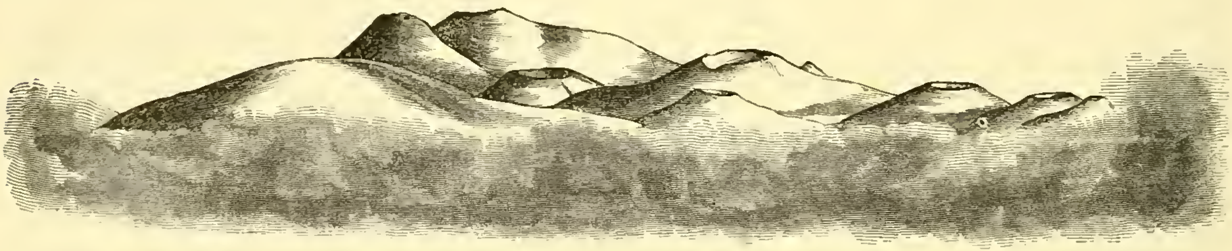


Fig. 33. The Summit of Hualalaì seen from Mauna Lòa (9000 feet).

In the afternoon we camped about a mile from our last night's resting-place, between two cones. Our guide shot two of the native geese (*Bernicla Sandvicencis*), which were fine eating. The number of these geese has been much underrated. Although they are found only on the highlands of Hawaii and Máui, their number admits of the annual slaughter of several hundred without sensible diminution. They build their nests in the grass, and lay two or three eggs, white, and about the size of a common goose's egg. They are web-footed, but are never seen in the water, indeed there is no water on the uplands, and their food is principally berries and a common species of *Hieracium*. The strawberries (*Fragraria Chiliensis*) were nearly out of season. Trees were comparatively small. The mamáne, a *Dodonæa*, sandal-wood, and an arborescent geranium, were the most common. Of the herbs a *Lythrum*, much resembling our native species, and many compositæ with brilliant yellow blossoms (*Raillardia, Artemisia, etc.*), were seen all through the plain.

I made me a bed of bracken (*Pteris aquilina*) as I might at home on a similar occasion, and with my feet towards a fire of great mamáne logs, went to sleep. The night was clear and cold, — so cold that I awoke and moved nearer the fire. It was strangely silent; the stars were shining brightly, and directly in front of me was the grand Mauna Lòa. At half-past three the moon rose over the slopes of Mauna Kéa, and I fell asleep again. In the morning at sunrise the thermometer marked 46° Fahr. As the sun rose, the lava-flow of 1859 was visible through its whole length from the summit of Mauna Lòa to the sea at Kawaihàe, shining like a river of silver, owing to its glossy black surface. How beautiful a sight it must have presented when it was a river of fire!

All the plain between the mountains, which covers many square miles, is intersected by lava-streams from all three summits, and is wholly rocky and uneven, with caves and beds of

[1] Ellis, *Tour of Hawaii*, p. 55.

[2] Prof. Dana estimates it at 10,000 feet.

a-a. The vegetation is scanty, but enough to support large flocks of wild goats. A road was attempted some years ago, by government, from Kailùa on the western coast to Hìlo across this plain, but only fifteen miles were ever built, and the natives dislike the cold of the mountain region too much to travel this way often. Caves are the only sources of water here, the surface being too porous to retain pools or streams; but in the caves the water drips from the roof, and is collected in calabashes.

The only recorded eruption of Hualalaì took place in 1800, and was seen by Turnbull.

Ellis gives the following account, taken from the lips of an Englishman and of natives, of this eruption[1]: —

"Stone walls, trees, and houses all gave way before it; even large masses of rocks of hard ancient lava, when surrounded by the fiery stream, soon split into small fragments, and, falling into the burning mass, appeared to melt again, as borne by it down the mountain's side. Offerings were presented, and many hogs thrown alive into the stream to appease the anger of the gods, by whom they supposed it was directed, and to stay its devastating course. All seemed unavailing, until one day the king, Kaméhaméha, went attended by a large retinue of chiefs and priests, and, as the most valuable offering he could make, cut off part of his own hair, which was always considered sacred, and threw it into the torrent. A day or two after, the lava ceased to flow. The gods, it was thought, were satisfied."

To this eruption is referred the sad story, often told to travellers by the natives, of the death of a mother and her infant. In 1800, as now, the base of Hualalaì had many small fishermen's hamlets along its shore. At night, while all were sleeping, the eruption began. The stream of lava came thundering down upon the people on the shore, and while nearly all succeeded in escaping, in one hut only the husband was awakened, and in his terror he fled leaving his wife and child. Before she was aroused by the shrieks of her friends, the lava had encircled the hut and escape was no longer possible. The lava set fire to the house, and the woman sprang into a pandanus-tree near by. But her refuge was of short avail, and the lava-stream, which was flowing into the sea, consumed, as it passed, the two human sacrifices to Pélé.

This latest effort of Hualalaì, besides destroying several small villages, and filling up fish-ponds, ended by changing the coast line for twenty miles from a bay to a headland several miles beyond the old coast. Nevertheless it was not an important eruption, nor equal to the dying effort with which Háleakala rent its vast crater, or Mauna Kéa piled up the monuments on its craterless head.

The remarkable rapidity with which this stream descended indicates great fluidity. It appears to have flowed fifteen miles in two or three hours. Its source was a little below the summit and it issued in two streams, one to the north-west and the other to the north-east. Twenty-three years after this Ellis found a warm spring at Kailùa where Glauber's Salts were formed by the action of sulphurous vapors on sea-water, and warm springs were also found at Kawaihàe at tide level. These are now cooled, and there are no visible signs of volcanic activity anywhere on the mountain. The streams which in former ages flowed at intervals down its sides do not appear to be of so great a volume as those from Mauna Lòa, and this is probably owing to the great number of vents. Their physical structure, however, is identical with that of those from the other craters.

[1] Ellis, *loc. cit.* p. 44.

Mauna Kéa. — In the early part of January 1841, Dr. Charles Pickering made the ascent of Mauna Kéa, and the following facts are taken mainly from his account.[1] On the 10th they left Hìlo, and on the 12th reached the limit of the forest, about six thousand feet above the sea. They passed a small but distinct lava-stream, and found the ground frozen, and the pools of water covered with thin ice. The surface was undulating, broken by ravines, and there were many conical hills varying in height from two to eight hundred feet. On the 14th, they came to a desolate gravelly plain many miles in extent, and an Arctic flora at once succeeded the vegetation of temperate climes. No lava-streams or clinkers were seen, and in the distance rose six peaks whose bases were rough with blocks of lava, while towards their tops scoriæ of a red color with gravel prevailed.

The highest peak is on the south, and near this Rev. Mr. Goodrich describes a lake twenty-five rods in diameter. The terminal peaks are truncated cones with craters within, and the angle of their outer slope is about 30°. The crater of Mokuawéowéo on Mauna Lòa was distinctly visible, being nearly on a level with the base of the summit cones. Caves in the lava were common, and in one of these a gentleman from Honolulu found a few years since a very curious idol, probably left there many years before by some of the natives who ascended the mountain to cut stone adzes and poi pounders, as a large pile of stone-chips was found near by. The stone used for these instruments is a solid phonolite containing much feldspar, and takes a good polish. The kinds most prized are found here and on Mauna Lòa, and, judging from the large piles of refuse, the manufacture from these quarries has been extensive.

Vegetation is more various than on Mauna Lòa and creeps up to the height of twelve thousand feet, while on the latter it extends to ten thousand on the windward and only seven thousand feet on the leeward. In the absence of tracts of pahoehoe and ridges of a-a the slope is comparatively smooth and the ascent to the terminal cones is easily made on horseback from the western side at Waiméa; the usual course being to ride up into the forest in the afternoon, spend the night there, and the next day visit the summit and return to this camp or even to Waiméa. In crossing the mountain to Hìlo through the valley of the Wailùku, it is necessary to proceed on foot, owing to the thickness of the jungle in the latter place. The northern ridges of Mauna Kéa have never been explored; and, as may be inferred from the deep valleys and abundant streams near the coast, are much more difficult of access than any other portion of Hawaii; but doubtless a rich harvest awaits the fortunate botanist who shall penetrate into this region.[2]

Mauna Lòa. — On Tuesday, August 2d, we left the hospitable house of Rev. J. D. Paris, the missionary at Kaáwalòa. The native magistrate, Kupaké, had heard of our intended journey and sent us two large dried fish, a most acceptable present, and a large water-bottle. We secured as a guide an old goat-hunter, Kaákakawaì, and we had also three native bearers and a pack-mule. For the first six or eight miles our road was the same as when we ascended Hualalaì, and, as then, we got wet through in passing the forest, this time by a thunder-storm of short duration. We camped at night on the mountain-plain near Judd's road, and in the morning sent back our horses, and prepared our raw-hide sandals for climbing over the rough lava, as there is no path for horses up the *smooth* dome of

[1] *Narrative of the United States Exploring Expedition*, vol. iv., p. 199.

[2] Mr. Mann and myself found more than thirty new species of plants in a region already partly explored.

Mauna Lòa. We went nearly east until we struck the flow of 1859, and then followed that up more than eight miles. The surface was black and shining and quite brittle, and as we walked over it, it sounded like a hard frozen crust of snow. The outer surface to the depth of half an inch, was very porous and readily separated from the harder interior. In many places the lava had flowed up hill, dammed up behind by its rapidly hardening crust; and it sometimes attained an elevation of twenty-five or thirty feet without breaking from its pipe. Bubbles of great size, some still perfect, others broken in, were very common, and in some of the caves thus formed, ferns were growing in the moist atmosphere. On the surface cracks also we found a *Polypodium*, but lichens were scarce. Here and there we came to a deep round hole, and by its side lay the bleaching tree that had been burned off. The clumps of shrubs often approached within twenty feet of the flow, but in other places they had been killed to a distance of fifty feet, probably by gases, as they were not at all charred.

Immense beds of a-a with almost perpendicular sides, crossed our way, sometimes at the edge, sometimes directly across the flow, but always more or less level on top. The roughness of this a-a was greater than any we had met before; and we needed the raw-hide sandals we had prepared for such places, as well as thick buckskin gloves to protect our hands from the sharp needle-like points. Often the deep canal which the fiery river had burned for itself, was visible through large breaks in the covering crust, and on approaching a hole of this nature, I found myself on the verge of a gulf a hundred feet deep, of unknown length, and, as nearly as I could see, two hundred feet wide. The bottom was rough and cracked, and covered with the fragments from the roof and sides, fallen since the lava had ceased to flow. The crust on which I stood was but a few inches thick, and although I had tested it with my staff before, I thought it safest to lie down and crawl until I had got several rods from the hole, and I did not venture near another.

The roughness of this flow at last turned us aside to the right on to the old pahoehoe, which is covered thinly with grass and small bushes along the numerous cracks. Mauna Lòa remained clear all day, and the summit did not seem very far off. Indeed, at seven o'clock in the evening when we decided to camp for the night, had it not been that we were still within the limit of vegetation, I should have been inclined to push on and reach the summit that night. The whole surface of the mountain is undulating, and as we reached what seemed to be the top, we found a shallow valley and another hill beyond, and so it was all the way. We got the most sheltered place we could find, as we had no tent, and there were not enough bushes to make a hut; Kaákakawaì shot a goat, and we ate our supper. The wind was quite cold, and we were not warm enough to sleep well, and while we were awake we saw a most novel sight,—what I may call an inverted sunset. The clouds had risen rapidly until they quite covered the plain and dashed their misty van against the base of the three giants, quite cutting them off from the rest of the world except Háleakala which towered above the mist. The surface of the clouds was rough and in constant motion, and as the sun sank into it, it seemed to kindle into flames of the most brilliant colors. All the golden canopy we usually see above the sun, was below it here, and above, all was clear The clouds swept up nearly eight thousand feet, but no higher, and we were soon asleep beyond their limits.

The morning was clear and not very cold, and the view of Hualalaì and Kéa was very grand. At seven o'clock we had eaten our morning meal, put out our fire, and started on our way. The craters of 1859 were just on our left as we went up, and for two miles the crevices were filled with the *limu* or Hawaiian pumice, which is green and very light, and with Pélé's hair. This fine volcanic glass was blown more than sixty miles during this eruption. At three o'clock two of our Kanakas gave out, and we were obliged to leave them, assuming their burdens ourselves. The others were sick, and bound their heads up with leaves, complaining that their heads and stomachs were affected, imputing it all to the wind, which, however, was very light. Mr. Mann and myself felt no inconvenience from the altitude during the journey.

At night we were about half a mile from the terminal crater, and we found a long narrow cave, once the bed of a small lava-stream, and still horrid with projecting points. It was five feet wide, two feet high, and of considerable length. We slept in Indian file, or rather tried to sleep; our bed was a magnified rasp, and although we broke off as many of the teeth as we could, more than enough remained. We needed all our blankets to protect us from the severe cold which froze water solid in the cave at our feet, but we had to push a fold beneath every time we turned. I got up before sunrise, and the air seemed intensely cold; I ran to a little hill and saw the sun come up through the clouds, and then crawled into the cave again and breakfasted. We then covered ourselves well with blankets, and walked up to the crater. Mokuawéowéo is the most perfectly formed crater on the Islands, although not the largest. The walls almost a thousand feet high, are nearly perpendicular and unbroken. When the United States Exploring Expedition ascended Mauna Lòa in 1841, the bottom was rough, and contained eight or ten cones, some of considerable height; now there were only two cones, about two hundred feet high each, near the eastern wall; the whole bottom had been overflowed with fresh black lava, and as examined with a powerful glass was no rougher than an ordinary lava-stream. We were on the highest wall, 13,790 feet above the sea, as determined by the Exploring Expedition, and on the opposite side from the Wilkes Encampment. On a small pile of stones was a sandal with the names of Paris, Alexander, Haskell, 1859. The sandal looked new and fresh as if just cut from the hide. I was told that a cow once strayed up here in search of water, and died, and her body was found dried and retaining its shape completely.

The hard compact gray stone of the summit and walls is much cracked, and exhibits deep strata as elsewhere. Scattered along the edges, and in various places over the great summit plain were large irregular masses of a solid reddish clink stone much used for stone axes, etc. Several immense cracks parallel with the crater walls extended some distance. These sometimes contained ice; and on breaking the surface, which was some two inches thick, we found a large supply of fine water in the ice, with which we replenished our water-bottles. No snow was visible, and it is a mistake to suppose these summits within the limits of perpetual snow, as is sometimes stated. Seldom in the summer is any snow found here except in the caves where it is preserved as in ice-houses. Snow frequently falls on both Mauna Lòa and Mauna Kéa, but, except in winter, it disappears as soon as the sun rises.

At first we did not see any signs of volcanic activity, but at last discovered steam issuing from the northern bank. Mr. Mann advised a descent into the crater, and we attempted it, but after climbing down more than half way gave it up. Mokuawéowéo was partly surveyed by the Exploring Expedition, and the plan given represents its present condition correctly. It is circular, 8000 feet in diameter, and on the northern and south-eastern ends are two semicircular depressions which increase its diameter to 13,000 feet in a north-by-west and south-by-east direction. On the west side the walls were, in 1841, seven hundred and eighty-four feet high, and on the east four hundred and seventy. The bottom of the pit as examined at that time consisted of solid lava, through which there were many fissures and fumaroles emitting steam and sulphurous vapors in large volumes. One of the fissures near the western bank had ejected lava at no very distant period.[1]

Adjoining Mokuawéowéo are two small pit craters on the major axis of the ellipse, and into the southern one a stream of lava has flowed from the main crater. The summit plain is much fissured, and several small cones both north and south, but on the same general line, mark eruptive agencies. The lava of the walls is largely phonolitic.

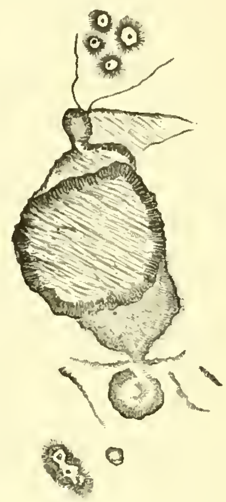


Fig. 34. Plan of Mokuawéowéo.

At nine o'clock we commenced the descent, as our time was limited, and about two in the afternoon a thick misty rain came on, and our guide wished to stop as he could not see the way; we had, however, three compasses, and proceeded without difficulty, although drenched, to the plain, where we found a cave and contrived to light a fire. At nine o'clock the rain ceased, the stars came out brightly, and as the cave still dripped, we rolled ourselves up in our blankets wet through as we were, and with our feet to the fire slept well all night. In the morning we wrung out our clothes, which dried in the course of two hours as we were walking rapidly in the sun, and about noon rested on the edge of the forest, several miles west of where we had come up, at a spring which, as they always are on this island, was in a very improbable place,—the most elevated part of an open plain. Its position was marked by a pile of stones; no stream ran from it, and it was carefully covered to keep the wild hogs out, whose marks we saw near by among the strawberries and on the trees. Striking into the woods we walked down at a rapid rate, although the muddiness of the path, and the many trees that had fallen across the way, made it very laborious. Added to this, it began to rain as we came into the region of ferns, and we were again wet through.

Vegetation on the leeward side of Mauna Lòa only extends to the height of six to seven thousand feet, but on the windward slopes to nearly ten thousand. By various calculations, Prof. Dana gives the average slope of the mountain at 6° 30′, while from Kilauéa to the sea it is but 1° 28′, or one hundred and thirty-five feet to the mile. A lava stream, however, in flowing down the side meets inclinations from 1° to 25°, so uneven is the ground.[2] Eruptions have occurred all over the summit, and although many of these lateral ejections have been of enormous volume, they still compose but a small portion of the solid mass of the mountain. They, however, play a very important part in determining the position of future valleys, should volcanic action ever cease, as in almost all cases they have formed deep chasms in the mountain sides.

History of Mauna Lòa. — The earliest eruption recorded took place in 1832, and it is rather remarkable that no traditions of the natives point definitely to any previous one. On the 20th of June, Mauna Lòa commenced to eject lava from the summit on several sides, and continued three or four weeks, with such brilliancy as to be visible at 1832.

[1] *Narrative of United States Exploring Expedition*, vol. iv., p. 152.

[2] The slope of Teneriffe is 12° 30′; Ætna, 8°, according to Élie de Beaumont; 10° 15′ according to Von Buch.

Lahaina, more than a hundred miles distant.[1] Through the summer earthquakes were frequent on Hawaii, although not severe, and finally Kilauéa burst into activity as described in the account of that volcano.

After an interval of eleven years, Mokuawéowéo again broke out. In 1837, Douglass made the first ascent of Mauna Lòa by a foreigner, and describes the crater as being in intense activity, but unfortunately his statements were so evidently false in other respects, that no reliance can be placed on his description. If the crater had been active, doubtless smoke, or the glare reflected on the sky, would have indicated the fact to the residents at the base of the mountain.

1843. The accounts of the eruption of 1843 are as follows, the first by Dr. Andrews in a letter dated February 6th, 1843[2]: —

"Smoke was first seen near the summit of the mountain, on Monday, January 9th. During the succeeding night a brilliant light was emitted from the same spot. The great distance of the mountain from Hìlo — about forty miles — prevented our seeing any thing more than the intense glare sent forth by the boiling mass, which apparently was pouring forth and rolling down the side. . . . During the day vast volumes of smoke were constantly pouring forth, concealing everything beneath. At times the smoke rose in a nearly perpendicular column, not less, as I judged, than one or two thousand feet high. Before the close of the week the light disappeared from the upper part of the mountain, and broke out anew near its base in the valley between it and Mauna Kéa."

The Rev. T. Coan writes under date of February 20th, 1843.[3] After describing the brilliancy of the light he says: "For about four weeks this scene continued without much abatement. At the present time, after six weeks, the action of the fire is greatly diminished, though it is still somewhat vehement at one or two points along the line of eruption. The flow of the lava has probably extended twenty miles." Soon after this he was able to visit the scene of eruption, and ascend the mountain, and writes in a letter dated April 5th: "The eruption has flowed from the summit of Mauna Lòa to the base of Mauna Kéa, where it separates into two broad streams, one flowing towards Waiméa, and the other towards Hìlo. Another great stream has flowed along the base of Mauna Lòa towards Mauna Hualalaì in Kóna. These streams are still flowing, and they have reached a distance of from twenty-five to thirty miles from the crater on the top of the mountain. The quantity of lava is immense, it being many miles wide. There are two great active craters in close contiguity near the summit. Lava does not flow from these craters now; it is conveyed down the side of the mountain in a subterranean duct from fifty to a hundred feet below the surface, at the rate of from fifteen to twenty miles an hour." The flow soon after ceased. Mr. Coan threw stones into the stream as it appeared through the openings in the crust, and they did not sink but were instantly carried along out of sight. Mounds, ridges, and cones were thrown up along the lava-stream, and from the latter, steam, gases, and hot stones were ejected.[4] The angle of descent of the whole distance is 6°, but in many places the stream was continuous at an inclination of 25°. Kilauéa was visited by Mr. Abner Wilcox during this eruption, but it showed no signs of sympathy with the summit crater.

1851. In 1851, a slight eruption took place from the summit of Mauna Lòa, which is thus described by Mr. Coan[5]: —

1 *Silliman's Journal*, [N. S.] vol. xxv., p. 199.

2 *Missionary Herald*, vol. xxxix., p. 381.

3 *Ibid.*, p. 463.

4 *Missionary Herald*, vol. xl., p. 44.

5 From a letter to the Rev. C. S. Lyman, by Rev. T. Coan, dated Hilo, Hawaii, Oct. 1, 1851. *Silliman's Journal*, [N. S.]

"On the 8th of August last a new eruption was seen on the western slope of Mauna Lòa, a few miles from its summit. All we could see at Hìlo was a white pillar of smoke by day and a brilliant fiery pillar by night. Owing to a canopy of clouds which much of the time shrouded the mountain, we obtained only occasional views of the eruption. At Ka-ù the view was less obstructed. The rising columns of light and smoke, as seen from some points in that district, were said to be gorgeous and glorious. A gentleman then surveying in Keàwa, of notorious and impressive memory, tells me that the light at that place was sufficient to enable him to read in the night. He also asserted that he heard several distinct detonations from the mountain, during the eruption, like the explosion of gases and the rending of rocks. This would be remarkable, as the distance to the point of eruption must have been thirty or forty miles.

"But the most magnificent scenes were witnessed on the western sides of the mountain in the district of Kóna. Enormous floods of rock in igneous fusion burst from an orifice supposed to be about five miles westward of Mokuawéowéo, the great crater where Capt. Wilkes encamped, and rolled down the western slope of the mountain towards Kaáwalòa in a stream from one to two miles wide, and perhaps ten miles long. You will, however, receive these statements as matters of opinion and conjecture and not of actual observation and exact measurement. The eruption continued but three or four days, and we had hardly time to admire its brilliant coruscations and its rousing demonstrations, before all was hushed in profound silence, and covered with a pall of darkness."

This eruption broke out about a thousand feet below the summit, or two hundred feet below the bottom of the terminal crater. Some observers declare that the smoke proceeded partly from Mokuawéowéo, but no one ascended the mountain. The large masses of ice almost always found in the caves and hollows near the summit may have been converted into steam. No jets were thrown up, and the fissure was soon closed. From the portion of this stream that I visited, I should estimate its dimensions at ten miles in length but less than a mile in average breadth, or in volume one hundred and sixty million cubic yards of lava. The greater part of this lava is the pahoehoe, although some a-a occurs, and the whole flow bears marks of rapid cooling. It followed very nearly the track of an eruption which broke down the western rim of Mokuawéowéo and flowed through Keálakeakùa. The noise of explosions may have proceeded from the bursting of the caves and air bubbles in this ancient flow where they are numerous.

Six months after this, Mauna Lòa broke forth again, and I again quote Mr. Coan's letter.[1] 1852.

"Old Kilauéa has been quite tame since I last wrote you. Changes have, however, taken place. The keystone of the great dome over Halemáumau (the lake) has parted, the top of the dome has fallen in, an orifice of about one hundred feet diameter has been opened, and an abyss of raging fire may be seen below at the depth of one hundred feet. Small lakes of fire have also broken out here and there in the crater, but the action has been partial and comparatively feeble. No light shines upon us from Kilauéa, and we have no new terrors to record of Mother Pélé at this point, but we have other wonders among the fiery sisterhood.

"At half-past three on the morning of the 17th ult., a small beacon-light was discovered

vol. xi., p. 395. It is said that Mokuawéowéo broke out in 1849.

1 From a letter to the same correspondent, dated Hìlo March 5th, 1852. *Silliman's Journal*, [N. S.] vol. xii., p. 219.

on the summit of Mauna Lòa. At first it appeared like a solitary star resting on the apex of the mountain. In a few moments its light increased and shone like a rising moon. Seamen keeping watch on deck in our port exclaimed, 'What is that? The moon is rising in the West!' In fifteen minutes the problem was solved. A flood of fire burst out of the mountain, and soon began to flow in a brilliant current down its northern slope. It was from the same point, and it flowed in the same line, as the great eruption which I visited in March 1843. In a short time immense columns of burning lava shot up heavenward to the height of three or four hundred feet, flooding the summit of the mountain with light, and gilding the firmament with its radiance. Streams of light came pouring down the mountain, flashing through our windows, and lighting up our apartments so that we could see to read large print. When we first awoke, so dazzling was the glare on our windows that we supposed some building near us must be on fire; but as the light shone directly upon our couch and into our faces we soon perceived its cause. In two hours the molten stream had rolled, as we judged, about fifteen miles down the side of the mountain. This eruption was one of terrible activity and surpassing splendor, but it was short. In about twenty-four hours all traces of it seemed to be extinguished.

"At daybreak on the 20th of February, we were again startled by a rapid eruption bursting out laterally on the side of the mountain facing Hìlo, and about midway from the base to the summit of the mountain. This lateral crater was equally active with the one on the summit, and in a short time we perceived the molten river flowing from its orifice direct towards Hìlo. The action became more and more fierce from hour to hour. Floods of lava poured out of the mountain's side, and the glowing river soon reached the woods at the base of the mountain, a distance of twenty miles.

"Clouds of smoke ascended and hung like a vast canopy over the mountain, or rolled off upon the wings of the wind. These clouds assumed various hues — murky, blue, white, purple or scarlet — as they were more or less illuminated from the fiery abyss below. Sometimes they resembled an *inverted* burning mountain with its apex pointing to the awful orifice over which it hung. Sometimes the glowing pillar would shoot up vertically for several degrees, and then describing a graceful curve, sweep off horizontally, like the tail of a comet, further than the eye could reach. The sable atmosphere of Hìlo assumed a lurid appearance, and the sun's rays fell upon us with a yellow, sickly light. Clouds of smoke careered over the ocean, carrying with them ashes, cinders, charred leaves, etc.; which fell in showers upon the decks of ships approaching our coast. The light was seen more than a hundred miles at sea, and at times the purple tinge was so widely diffused as to appear like the whole firmament on fire. Ashes and capillary vitrifactions called 'Pélé's hair' fell thick in our streets and upon the roofs of our houses. And this state of things still continues, for even now while I write, the atmosphere is in the same yellow and dingy condition; every object looks pale, and sickly showers of vitreous filaments are falling around us, and our children are gathering them.

"As soon as the second eruption broke out I determined to visit it. Dr. Wetmore agreeing to accompany me, we procured four natives to carry our baggage, one of them, Kekai acting as guide. On Monday the 23d of February, we all set off and slept in the outskirts of the great forest which separates Hìlo from the mountains. Our track was not the one I took in 1843, namely, the bed of a river; we attempted to penetrate the thicket at another point, our general course bearing south-west. In ancient days an Indian trail had been beaten through in this direction, but it was now entangled with jungle so that all traces of it were nearly obliterated. However, we plunged into the forest with a long knife, hatchet, and clubs, and cut and beat our way at the rate of one and a fifth miles an hour. At night we slept in the bush and listened to the distant roar of the volcano. On Wednesday the 25th, we gained a little eminence in the woods, from which we could see the lava-stream which was now opposite us on our left, distant six miles. This fiery flood was now half way through the forest, and more than three fourths of the way from the crater to the shore, sweeping all before it. Apprehending that it might reach the sea in a day or two, and that the ladies at the station might be alarmed, Dr. Wetmore determined to return. Taking one of the natives and leaving three with me, he retraced his steps while I pushed on through jungle and bog and dell, beating every yard of my way out of this horrible thicket. On the 26th, we emerged from the forest but plunged at once into a dense fog more dark than the thicket itself. Pushing up the mountain we encamped for the night on a rough bushy ridge. A little before sunset the fog rolled off, and Mauna Kéa and Mauna Lòa both stood out in grand relief; the former robed in a fleecy mantle almost to its base, and the latter belching out floods of fire from its burning bowels. All night long we could see the glowing fires, and listen to the awful roar of the fearful crater.

"We had now been out four nights, and were within twenty miles of the crater, with the long brilliant river of fusion on our left shining in a line of light down the side of the mountain till it entered the woods. We left our mountain aerie on the 27th, determined if possible to reach the seat of action on that day. Taking the pillar of fire and cloud as our mark, and still having the great river of lava on our left, we pushed on over a rough and almost impassable surface — the attraction increasing as the square of the distance decreased. Our intense interest mocked all obstacles. At noon we came upon the confines of a tract of naked scoriæ so intolerably sharp and jagged that our baggage-men could not pass it. Here I ordered a halt; stationed the two carriers, gave an extra pair of strong shoes to my guide, gave him my wrapper and blanket, put a few crackers and boiled eggs into my pockets, took my compass and staff, and said to Mr. Salt Sea (Kekai), 'Now go ahead, and let us warm ourselves to-night by that fire yonder.' Thus equipped we pressed up the mountain, over fields of lava of indescribable roughness; now mounting a ridge of sharp and vitreous scoriæ (a-a), where the fiery pillar stood full in view, and then plunging into some awful ravine or pit, from which we slowly emerged by crawling upon 'all fours.' But I soon found that my guide needed a leader. He was too slow. I therefore pressed ahead, leaving him to get on as best he could. At half-past three P. M. I reached the awful crater and stood alone in the light of its fires. It was a moment of unutterable interest. I seemed to be standing in the presence and before the throne of the eternal God; and while all other voices were hushed, His alone spake. I was ten thousand feet above the sea, in a vast solitude untrodden by the foot of man or beast; amidst a silence unbroken by any living voice, and surrounded by scenes of terrific desolation. Here I stood almost blinded by the insufferable brightness; almost deafened with the startling clangor; almost petrified with the awful scene. The heat was so intense that the crater could not be approached within forty or fifty yards on the windward side, and probably, not within two miles on the leeward. The eruption, as before stated, commenced on the very summit of the mountain, but it would seem that the lateral pressure of the embowelled lava was so great as to force itself out at a weaker point in the side of the mountain; at the same time cracking and rending the mountain all the way down from the summit to the place of ejection. The mountain seemed to be siphunculated; the fountain of fusion being elevated some two or three thousand feet above the lateral crater, and being pressed down an inclined subterranean tube, escaped through this valve with a force which threw its burning masses to the height of four or five hundred feet. The eruption first issued from a depression in the mountain, but a rim of scoriæ two hundred feet in elevation had already been formed around the orifice in the form of a hollow truncated cone. This cone was about half a mile in circumference at its base, and the orifice at the top may be three hundred feet in diameter. I approached as near as I could bear the heat, and stood amidst the ashes, cinders, scoriæ, slag and pumice, which were scattered wide and wildly around. From the horrid throat of this cone vast and continuous jets of red-hot and sometimes *white-hot* lava were being ejected with a noise that was almost deafening, and a force which threatened to rend the rocky ribs of the mountain, and to shiver its adamantine pillars. At times the sound seemed subterranean, deep, and infernal. First, a rumbling, a muttering, a hissing or deep premonitory surging; then followed an awful explosion, like the roar of broadsides in a naval battle, or the quick discharge of park after park of artillery on the field of carnage. Sometimes the sound resembled that of ten thousand furnaces in full blast. Again it was like the rattling of a regiment of musketry; sometimes it was like the roar of the ocean along a rock-bound shore; and sometimes like the booming of distant thunder. The detonations were heard along the shores of Hilo. The eruptions were not intermittent but continuous. Volumes of the fusion were constantly ascending and descending like a *jet d'eau*. The force which expelled these igneous columns from the orifice, shivered them into millions of fragments of unequal size, some of which would be rising, some falling, some shooting off laterally, others describing graceful curves; some moving in tangents, and some falling back in vertical lines into the mouth of the crater. Every particle shone with the brilliancy of Sirius, and all kinds of geometrical figures were being formed and broken up. No tongue, no pen, no pencil can portray the beauty, the grandeur, the terrible sublimity of the scene. To be appreciated it must be felt. . . . During the night the scene surpassed all power of description. Vast columns of lava at a white-heat shot up continuously in the ever-varying forms of pillars, pyramids, cones, towers, turrets, spires, minarets, etc. While the descending showers poured in one incessant cataract of fire upon the rim of the crater down its burning throat, and over the surrounding area,—each falling avalanche containing matter enough to sink the proudest ship. A large fissure opening through the lower rim of the crater gave vent to the molten flood which constantly poured out of the orifice, and rolled down the mountain in a deep, broad river, at the rate, probably, of ten miles an hour. This fiery stream we could trace all the way down the mountain until it was hidden from the eye by its windings in the forest, a distance of some thirty miles. The stream shone with great brilliancy in the night, and a long horizontal drapery of light hung over its whole course. But the great furnace on the mountain was the all-absorbing object.

"*March* 6. The fire has not yet reached the shore, and it may not. It is winding in the woods, filling our atmosphere with smoke, and sending down showers of ashes, charred leaves, etc. The great furnace in the mountain is still in terrible blast. No decrease of activity, but rather an *increase*."

In a letter dated September 27th, 1855, Mr. Coan says: "On the evening of the 11th of August, a small point glowing like Sirius, was seen at the height of twelve thousand feet on the north-western slope of Mauna Lòa. This radiant point rapidly expanded, throwing off coruscations of light, until it looked like a full-orbed sun."[1] 1855.

Sixty-five days after, the fissure which permitted the escape of the lava was still open, and in awful activity. The stream was flowing directly towards Hìlo and there were no valleys or ridges of sufficient size to turn its course. The inhabitants of this beautiful village were exceedingly anxious, and made frequent excursions to the scene of the lava-flow. On the 2d of October, Mr. Coan with a party of friends passed through the thick forest, following the course of the Wailùku, and on the fifth reached the lava-stream early in the morning, at a narrow point where it was about three miles wide. "In some places it spread out into wide lakes and seas, apparently from five to eight miles broad, enclosing, as is usually the case, little islands not flooded by the fusion." Mr. Coan continues in this letter, which is dated Oct. 15th, 1855[2]: —

"Early on Saturday, the 6th, we were ascending our rugged pathway, amidst steam and smoke and heat which almost blinded and scathed us. At ten we came to open orifices down which we looked into the fiery river which rushed furiously beneath our feet. Up to this we had come to no open lake or stream of active fusion. We had seen in the night many lights like street-lamps, glowing along the slope of the mountain at considerable distances from each other, while the stream made its way in a subterranean channel, traced only by these vents. From ten A. M. and onward, these fiery vents were frequent, some of them measuring ten, twenty, fifty, or one hundred feet in diameter. In one place only, we saw the river uncovered for thirty rods and rushing down a declivity of from ten to twenty-five degrees. The scene was awful, the momentum incredible, the fusion perfect (a white-heat), and the velocity forty miles an hour. The banks on each side of this stream were red-hot, jagged and overhanging, adorned with burning stalactites and festooned with immense quantities of filamentose, or capillary glass, called 'Pélé's hair.' From this point to the summit crater all was inexpressibly interesting.

"Valve after valve opened as we went up, out of which issued 'fire and smoke and brimstone,' and down which we looked as into the caverns of Pluto. The gases were so pungent that we had to use the greatest caution, approaching a stream or an orifice on the windward side, and watching every change or gyration of the breeze. Sometimes whirlwinds would sweep along, loaded with deadly gases, and threatening the unwary traveller. After a hot and weary struggle over smoking masses of jagged scoriæ and slag, thrown in wild confusion into hills, cones, and ridges, and spread out over vast fields, we came at one P. M. to the terminal or summit crater (not Mokuawéowéo).

"This we found to be a low elongated cone, or rather a series of cones, standing over a great fissure in the mountain. Mounting to the crest of the highest cone, we expected to look down into a great sea of raging lavas, but instead of this the throat of the crater, at the depth of one hundred feet, was clogged with scoriæ, cinders, and ashes through which the smoke and gases rushed up furiously from seams and holes. One orifice within this cone was about twenty feet in diameter, and was constantly sending up a dense column of blue and white smoke which rolled off in masses and spread over all that part of the mountain,

[1] *Silliman's Journal*, [N. S.] vol. xxi., p. 144.

[2] *Ibid.*, p. 139.

darkening the sun, and obscuring every object a few rods distant. So toppling was the crest of this cone, so great the heat, and so deadly the gases, that we could find no position where we could look down the throat or orifice; and could we have done so, it is not probable that we should have seen the deep fountain below us, as the lavas were forced up its horrid chimney from the burning bowels of the earth. I have no doubt that the point at which the igneous river flowed off in its lateral duct was at least five hundred, perhaps a thousand feet below us.

"The summit cone which we ascended was about one hundred feet high, say five hundred feet long and three hundred broad at its base. Several other cones below us were of the same form and general character, presenting the appearance of smoking tumuli along the upper slope of the mountain. As you descend the mountain these cones become lower and less frequent, but here they are the rims or jagged jaws of those orifices through which we look into that subterranean tube of angry fusion which hurries with such fearful speed down the side of the mountain. The molten stream first appears some ten miles below the fountain crater, and as we viewed it rushing out from beneath the black rocks, and, in the twinkling of an eye, diving again into its fiery den, it produced indescribable feelings of awe and dread.

"This summit crater I estimate at twelve thousand feet elevation; the principal stream (there are many lesser and lateral ones) including all its windings, sixty miles long; average breadth, three miles; depth, from three to three hundred feet, according to the surface over which it flowed. The present eruption is between those of 1843 and 1852, and from our high tower we could see them both and trace their windings.

"Early on Monday we decamped and set our faces for Kilauéa, distant some thirty-five miles, hoping by a forced march to reach it at night. At eight A. M., we passed the seat of the grand eruption of 1852, and travelled for miles on its cinders. A little steam only issues from that cone whose awful throat, in 1852, sent up a column of glowing fusion to the height of a thousand feet. We explored Kilauéa, and on Thursday reached Hìlo.

"Hìlo is now in a state of solemn and thoughtful suspense. The great summit fountain is still playing with fearful energy and the devouring stream rushes madly down towards us. It is now about ten miles distant, — nearly through the woods, following the right bank of the Wailùku, and heading directly for our bay.

"*October* 22. It is now seventy-two days since the eruption commenced, and the fountain is in full force. The matter disgorged is of the same general character as in former eruptions. We saw nothing new. Among the salts, sulphur, and sulphate of lime are the most abundant. They are scattered freely at several points along the line of flow."

Mr. Coan, it will be seen, struck the flow at a point above the terminus and followed it to its source. On his return he determined to cut through the forest and meet the stream. Following a branch of the Wailùku in a drenching rain which made the stream almost impassable, he thus describes the scene:[1] —

"So soon as we entered this stream we found it discolored with pyroligneous acid from burning wood, whose odor and lustre became more and more positive the further we advanced up the stream. The discoloration also became more apparent as we proceeded, until the water was almost black. This showed that the lava flow had crossed the head waters of the stream and its small tributaries, consuming the forest and jungle, and sending down what could not be evaporated of the juices to mingle with the stream.

[1] *Silliman's Journal*, [N. S.] vol. xxi., p. 237. The letter is dated Nov. 16, 1855.

"A little before sundown our guide led us at right angles from the stream we had been threading for six hours, and in a few minutes the fires of the volcano glared upon us through the woods. We were within six rods of the awful flood which was moving sullenly along on its mission towards Hìlo. Thrusting our poles into the lava, we stirred it, and dipped it up like pitch, taking out the boiling mass, and cooling all the specimens we desired. We were on the right or southern verge of the stream, and we also found that we were about two miles above its terminus, where it was glowing with intense radiance and pushing its molten flood into the dense forest which still disputed its passage to the sea.

"We judged the stream to be two or three miles wide at this point, and over all this expanse, and as far as the eye could see above, and down to the end of the river, the whole surface was dotted with countless fires, both mineral and vegetable. Immense trees which had stood for hours, or for a day, in this molten sea, were falling before and below us, while the trunks of those previously prostrated were burning in great numbers upon the surface of the lava.

"You are aware that the great fire-vent on the mountain discharges its floods of incandescent minerals into a subterranean pipe which extends, at the depth of from fifty to two hundred feet, down the side of the mountain. Under this arched passage the boiling lava hurries down with awful speed until it reaches the plains below. Here the fusion spreads out under a black surface of hardened lava some six or eight miles wide, depositing immense masses which stiffen and harden on the way. Channels, however, winding under this scorified stratum, conduct portions of the lava down to the terminus of the stream, some sixty-five miles from its high fountain. Here it pushes out from under its mural arch, exhibiting a fiery glow, across the whole breadth of the stream. Where the ground is not steep, and where the obstructions from trees, jungle, depressions, etc., are numerous, the progress is very slow, say one mile a week.

"On the evening of our arrival we encamped within ten feet of the flowing lava, and, as before stated, on the southern margin of the stream, some two miles above its extreme lower points. Here under a large tree, and on a bank elevated some three feet above the igneous flood which moved before us, we kept vigils until morning. During the whole night the scene was indescribably brilliant and terribly sublime. The greater portion of the vast area before us was of ebon blackness, and consisted of the hardened or smouldering flood which had been thrown out and deposited here in a depth of from ten feet to one hundred.

"Not only was the lava, as aforesaid, gushing out at the end of this layer, but also at its sides. These lateral gushings came out before and behind us, and two thirds surrounded our camp during the night, so that in the morning, when we decamped, the fusion was just five feet, by measurement, in front of us, six feet in our rear, and three feet, or the diameter of the trunk of our camp-tree, on our left. The drenching rain and our chilled condition induced us to keep as near the fire as we could bear it. Evening and morning we boiled our tea-kettle and fried our ham upon the melted lavas, and when we left, our sheltering tree was on fire."

Mr. Coan made several attempts to cross the lava-flow, "but the hardened surface of the stream was swelling and heaving at innumerable points by the accumulating masses and the upraising pressure of the lava below; and valves were continually opening, out of which the molten flood gushed and flowed in little streams on every side of us. Not a square rod could be found on all this wide expanse, where the glowing fusion could not be seen under our feet through holes and cracks in the superincumbent stratum on which we were walking. The open pots and pools and streams we avoided by a zigzag course; but as we advanced, these became more numerous and intensely active, and the heat becoming unendurable, we again beat a retreat after having proceeded some thirty rods upon the stream. It may seem strange to many, that one should venture on such a fiery stream at all, but you will understand that the greater part of the surface of the stream was hardened to the depth of from six inches to two or three feet; that the incandescent stream flowed nearly under this crust like water under ice, but showing up through ten thousand fissures and breaking up in countless pools. On the hardened parts we could walk, though the heat was almost scorching, and the smoke and gases suffocating. We could even tread on a fresh stream of lava only one hour after it had poured out from a boiling caldron, so soon does the lava harden in contact with the air."

Although the stream of lava continued to move for more than a year after in parts of its course, its front became cold and fixed on the banks of the river, and a Merciful Providence listened to the prayers of the people of Hìlo.

Prof. Dana considered it most probable that a fissure had extended completely down the mountain-side, and that the lava issued from many vents along this line.[1]

March 7th, 1856, Mr. Coan writes[2]: "The great fire-fountain is still in eruption, and the terminus of the stream is only five miles from the shore. The lava moves slowly along on the surface of the ground, and at points where the quantity of lava is small, we dip it up with an iron spoon held in the hand. During the last three weeks the stream has made no progress towards Hìlo, and we begin to hope that the supply at the summit-fountain has diminished. There is, however, still much smoke at the terminal crater. You will understand that the molten flood is all poured out of the fissures on the summit and for a few miles down the slope of the mountain. At first this disgorgement flowed down and spread wide on the surface of the mountain, as blood flows down a punctured limb. This phenomenon continued until the stream had swept down some thirty miles, which it did in about two days. It now came upon a plane where the angle of slope was small, say one degree. Here its progress became slow, it spread more widely, and refrigeration was more rapid. The surface of course hardened first. But this refrigerating process went deeper and deeper like the congelation of water, and extended higher and higher up the mountain until at length all the lava was covered, except at occasional vents — as heretofore described — for the escape of steam and gases.

"The process of breaking up vertically and spreading out afresh upon the hardened crust, was occasioned by obstructions at the end of the stream, damming up the liquid, and thus obliging the accumulating lavas to force new passages and outlets for disgorgement. In this way the stream was widened by lateral outgushings, divided into several channels, swayed to the right and left, and raised to great heights by pushing up from below, and heaping mass after mass upon what *had been* its upper stratum. Often when the stream had been flowing briskly and brilliantly at the end, it would suddenly harden and cool, and for several days remain inactive. At length, however, immense areas of the solidified lava, four, five or six miles *above* the end of the stream, are seen in motion — cones are uncapped — domes crack — hills and ridges of scoriæ move and clink — immense slabs of lava are raised

[1] *Silliman's Journal*, [N. S.] vol. xxi., p. 241. [2] *Ibid.*, vol. xxii., p. 240.

vertically or tilted in every direction, while a low sullen crash is heard from below. While you gaze in mute amazement, and feel the solid masses of rock, often thirty, fifty, or seventy feet thick, moving under your feet, the struggling lava oozes out through ten thousand orifices and fissures over a field of some four or five square miles. More than once have I been on such a field, and heard, and seen, and felt more than is here or can be described. And yet the action of the lava is so slow, in the conditions described, that there is no fear, and little danger to one well acquainted with such phenomena.

"During the night of the 29th of January, the molten stream poured continuously over a precipice of fifty feet, into a deep, dry basin half filled with flood-wood. The angle down which this fire cataract flowed, was about seventy-five degrees: the lava was divided into two, three, and sometimes four channels from one to four yards wide, and two or three feet deep. The flow was continuous down the face of this precipice from two P. M. until ten the next morning, when we left. During the night the immense basin under the fall was filled, the precipice converted into an inclined plane of about four degrees, and the burning stream was urging its way along the rocky channel below. But the scene on the night of the 12th of February was, in some respects, more gorgeous still, as it combined the element of water with that of fire. A stream of lava from twenty to forty yards wide had followed the rocky and precipitous bed of a river, until it was two miles in advance of the main lava-flow, which was nearly two miles broad. Beating our way through the thicket we came upon the terminus of this narrow stream of lava, near sunset. It was intensely active, and about to pour over a precipice of thirty-nine feet (by measurement), into a basin of deep water, large enough to float a ship. Before dark the lava began to fall into the water, first in great broken masses, like clots of blood; but in a short time in continuous, incandescent streams, which increased from hour to hour in volume, in brilliancy, and in rate of motion. The water boiled and raged with fearful vehemence, raising its domes and cones of ebullition ten feet high, and reflecting the red masses of fusion like a sea of fire mingled with blood.

"We encamped on the bank of the river, about fifty feet below the fiery cataract, and exactly opposite the basin of water into which the lava was flowing, twenty feet only from its rim. The face of this precipice was an angle of about eighty degrees, and the lava flowed down it briskly and continuously, in streams from one to four feet deep, during the night. Before morning this whole body of water, some twenty feet deep, was converted into steam, and the precipice became a gently inclined plane.

"I have seen continuous lava-streams flow rapidly down the sides of the mountain from ten to probably fifty feet deep. Lava flows at any depth, or any angle, and at any rate of progress from twenty feet an hour to forty miles."

To make the fact that the fissure did not extend to the base of the mountain more clear, Mr. Coan again writes under date of October 22d, 1856; he had then visited the flow seven times.

"A fracture or fractures occurred near the summit of the mountain, which extended in an irregular line from the terminal point, say five miles down the north-east slope of the mountain. From this serrated and yawning fissure, for two to thirty yards wide, the molten flood rushed out and spread laterally for four or five miles, filling the ravines, flowing over the plains, and covering all those high regions, from ten to one or two hundred feet deep. Along this extended fissure, elongated cones were formed at the points of the greatest activity. These cones appear as if split through their larger diameter, the inner sides being perpendicular or overhanging, jagged and hung with stalactites, draped with filamentous vitrifications, and encrusted with sulphur, sulphate of lime, and other salts.

"The outside of these cones are inclined planes, on an angle of forty to sixty degrees, and composed of pumice, cinder, volcanic sand, tufa, etc. You will not, however, understand that these semi-cones were once entire, and that they have been *rent*. They are simply masses of ridges of cinder and dross deposited on each side of the fractures where the action is greatest. *It is all a new deposit.* After you leave the region of open fissures, near the summit of the mountain all below *appears to be a flow on the surface.*

"1st. We can *see* no chasms or fractures except those always found in the surface flows. There is no visible evidence that the old substrata had been fractured, except on the higher regions of the mountain.[1]

"2d. Where there is a throat extending down to the fiery abyss below, there will, we think, always be a column of smoke and gaseous vapor ascending to mark the spot, so long as action continues. This is true of Kilauéa, and it is also true of *all* the eruptions I have noticed. Now if you were at Hìlo, you would see a continuous volume of smoke ascending from the terminal point, and another from the terminus of the stream — separated in a direct line forty miles, and by route of the flow seventy miles — while between these extreme points you see no smoke and have no evidence of fire beneath,[2] except the radiation of heat as you pass up. The smoke at the fountain is mineral, that at the end of the stream is from vegetation, and only here the fusion now makes its appearance, having come, as I believe, all the way from the mountain under cover, without showing itself at a single point. I do not mean that it has tunnelled the mountain, or melted a lateral duct through its mural sides. The process is this: lavas flowing on the surface and exposed to the atmosphere, unless moving with great velocity, as down steep hills, soon refrigerate on the surface. This hardened surface thickens, until it extends downward from one to two hundred feet, as the case may be. Under this superstratum the lava remains liquid; consequently at the termini and sometimes along the margins of the hardened streams, you see the fusion gushing out in red lines and points, and in irregular masses. When lavas refrigerate through the whole stratum, and thus rest upon an ancient or previous formation, they form dams which divert the stream of lava from above, unless this obstruction is broken up, tilted, or overflowed by fresh lava. Down the steep sides of the mountain such obstructions occur more rarely; consequently the lava ceases to reach the surface either at the fountain or down the sides of the mountain, but is confined to channels, mostly covered with fresh, solidified lavas, where it finds a free and rapid passage to the plains below. Here the movement is slow, the obstructions more numerous, and the force to overcome them less patent. This accounts for the spreading laterally, the upliftings, and the ten thousand irregularities which diversify the ever-changing surface of lava-streams. I have seen a dome, some three hundred feet in diameter at base, raised one hundred feet high, and split from the summit in numerous radii, through which the red and viscid fusion was seen; and I have mounted to the top of such a dome in this state, thrust my pole

[1] A careful examination of the line of eruption resulted in the conviction that the fissure was originally very small, not exceeding three or four feet, and did not extend below the point where the lava first reached the surface.

[2] This has been the case for some eight months. At first the whole ridge of the mountain was lighted with fusion on the surface; afterwards no fire was seen except at the end of the stream near Hilo. — *Note by Mr. Coan.*

into the liquid fire and measured the thickness of its shell, which was from two to five feet.

"Wherever vegetable matter is being consumed there is smoke; when this is exhausted there is none. Consequently I argue that there are no fissures extending to the central fires of the earth, except for a few miles near the summit of the mountain.

"3d. Again, and what is more reliable, I have surveyed the ground upon which lava-streams have been approaching, for distances of five to twenty miles, and have seen the burning flood move on, covering to-day the ground on which I travelled yesterday, and consuming the hut where I slept; and the process is so familiar that it is difficult to see how I can be mistaken.

"I *think* that this stream of lava is *now flowing* more than sixty miles longitudinally under its own refrigerated cover; but I may be mistaken. No fire is *seen* anywhere except at the end of the stream. Here it still pushes out and spreads and heaps with little abatement, while the great mountain furnace sends up large and continuous volumes of smoke."[1]

To this exceedingly full and minute account, I need only add that I visited the terminus of the stream, where it ceased to flow, in 1865, and found the whole appearance of the stream in strict accordance with Mr. Coan's account. The surface was horribly rough and piled with slabs of hardened crust in vast ridges extending for miles. I slept on the fresh lava and examined the structure minutely, and found nothing to distinguish this stream from other eruptions, except its broken condition, arising from the wet soil over which it passed, which raised the surface into huge blisters. Where the lava fell into the water it was shivered into coarse sand like the deposit near Honolulu, and as the water was evaporated the pahoehoe covered the ground almost entirely and even penetrated its mass. The angles down which the continuous stream of lava fell were as large as Mr. Coan mentions, and the lava does not seem much more cellular here than on level ground.

At the lowest edge of the lava flow, I found, on the more ancient rock beneath, rounded masses of red earth of the consistency of putty, and as large as a man's head. They were in considerable number, and seemed to have been pushed along by the lava; their softness was owing to the rain, as when dried they became as hard as dried potter's clay.[2] The surface of the lava was covered with a minute lichen on which vast numbers of succineas had been feeding.

A letter from Prof. R. C. Haskell of Oáhu College, gives the following very full account of the important eruption of 1859: — 1859.

"Our party consisted of Prof. Beckwith, Prof. Alexander, myself, and twenty students of the College. Twelve of us went to the source of the flow. . . . The eruption broke out on the 23d of January. No earthquake was felt in any part of the island at the time, but dead fish were noticed on the 21st and a few days afterwards, to the east of Molokaì, and between Molokaì and Oáhu. The fish gave no evidence of disease but seemed to have been parboiled. At Honolulu, two hundred miles from the eruption, the atmosphere was exceedingly thick and hazy. So much was this the case that it caused considerable excitement, before the news of the eruption arrived.

"Rev. Mr. Lyons of Waiméa states that on Sunday afternoon, January 23d, smoke was

[1] *Silliman's Journal*, [N. S.] vol. xxiii., p. 435.

[2] These masses were mostly composed of ferruginous oxides, as will be seen below.

seen gathering on Mauna Lòa. In the evening, lava spouted up violently near the top of the mountain on the north side, and apparently flowed both towards Hìlo and towards the west side of the island. This continued but a few minutes, when at a point considerably farther below the top, and farther west, another jet spouted up.

"Accounts from Hìlo say, that on the night of the 23d, it was so light there that fine print could be read without difficulty. After the 23d, the light was much less. At Lahaìna, more than one hundred miles distant, the whole heavens in the direction of the eruption were lighted up.

"Our party started from Honolulu, February 1st, and reached Keálakeakùa on the 3d. Here we learned that the stream from the eruption had reached the sea on the 31st of January, at Wainanalíi, about forty [sixty] miles from the place of eruption. This makes the average progress of the stream above five [seven] miles per day. After procuring guides, natives, pack-oxen, and mules, we started for the source of the flow on the 5th. About noon we had a view of the source, distant from us, probably, twenty-five miles in an air-line. The crater was about one hundred and fifty feet high, and two hundred feet in diameter (as we afterwards estimated). From within this crater, liquid lava was spouting up to the height of three or four hundred feet above the top. In shape and movement it resembled a mighty fountain or jet of water, though more inconstant. At one moment it was uncommonly high and quite narrow at the top, at the next not as high but very broad. At night, and from a good position near, the view of the jet, according to Mr. Faudrey (the only man who reached the crater while the jet was spouting) was grand beyond all description.

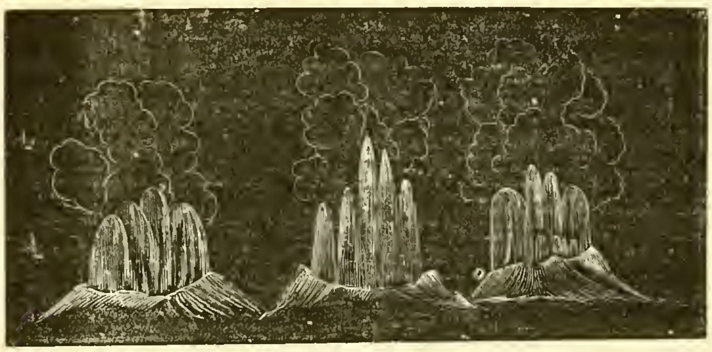


Fig. 35. Views of the Lava Fountain seen February 6th and 7th, 1859.

"Owing to an accident which befell one of our party, and the failure of water where it was supposed to be abundant, we were delayed two days and induced to divide our party into two divisions. One part returned to visit the flow at a point some twenty miles below, by another and easier route. The party who went on, consisting of twelve white persons and thirty kanakas, reached the crater Wednesday evening February 9th, and encamped about two miles from it. Here all fears about water were at an end, for we found snow in abundance within half a mile of our camping-ground. In the evening the view was magnificent. The jet had ceased to play; but two craters, about eighty rods apart, were sending up gas and steam, with appearances of flame. This apparent flame, however, we afterwards ascertained was only fine particles heated to redness. The noise attending this action was like that of an ascending rocket, very much increased of course, but quite irregular. About half a mile below the lower of the two craters, the stream first made its appearance. For five or six miles its course was well defined, and there were no side streams. From this point the main stream divided more or less, and on the plain, between the three mountains Hualalaì, Kéa, and Lòa, the branches extended over a breadth of three or four miles. Some of these streams were very broad and sluggish and partially cooled, some were narrow and running, as it seemed, at the rate of two or three miles per hour, burning the jungle and trees before them, and vying with each other in their work of destruction.

"For the first few miles the stream appeared to be a succession of cataracts and rapids. As it approached the plain between the two mountains, it gradually changed into a network of streams, or a lake of fire, embracing numerous islands and sending out streams on all sides. The color of the stream upon its first appearance was a light red approaching to white; on the plain a deep blood-red. From the plain towards Wainanalii the stream was narrow, varying from half a mile to a mile in width, and showing only a dull reddish light. . . . The next morning we were able to make some explorations about the craters. On the windward side we could ascend them and look in, though the heat was so great that we could look for a moment only, before turning our faces away. The sulphurous gases also were so strong that we were obliged to close our mouths and noses as we approached to look in. The craters were both very irregular in shape not only on the outside but on the inside. No liquid lava was seen in either at the time. In each there were two or three separate holes where gases and steam were issuing. The sides of these holes, and indeed the entire bottom of the craters, were at a white heat. The lava-stream appeared to be running underneath these craters, and the holes within seemed to be merely vents for the escape of gases. The craters were formed of fragments of light scoriæ and lava combined. The lower of the two (the one from which the jet was thrown up for fifteen days) was now open on the lower side. This was not the case while the jet was thrown up, according to Mr. Faudrey. . . . The upper crater was closed on all sides.

"Above these two craters we visited a third not then in action, but still hot. This was smaller and open on the lower side, and broken down somewhat on the upper side. This was formed not so much of scoriæ as of old lava. Above this we could see others of the same kind, and it is probable that they extend to the place where the lava first spouted out. From that place to the craters then in action, the stream appears to have flowed under the surface mostly, but to have been forced up to the surface, where these craters, now inactive. appear, by hydraulic pressure, or by the pressure of gases; or by both combined.

"The next morning we visited the point where the stream first made its appearance. Here we found the lava rushing out of its subterranean passage, and dashing over cataracts and along rapids at such a rate that the eye could scarcely follow it. The lava was at a white heat, and apparently as liquid as water. Only a few feet from where the stream issued, small masses of lava were thrown up from ten to fifty feet into the air, which cooled in falling. The cause of this was without doubt the escape of gas, and we then thought that the gas might come from the stream itself. But about three hours afterward we returned to the same place, and found that the action had greatly increased. Gases were escaping at two other points (Fig. 36 *b* and *c*) a few rods below the point first seen. Pieces of lava were thrown as high as one hundred and fifty feet, and at the lowest of the three points (Fig. 36 *a*), there was a fountain twenty-five feet high. The bits of lava thrown up cooled as they fell, and had already

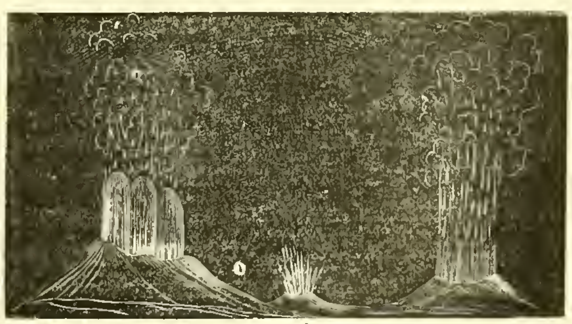


Fig. 36. Lava fountain of February 10th, 1859.

formed craters ten feet high around two of the points where gases were escaping. It was now evident that the escaping gases were not derived from the stream simply, but issued from a vent, which reached to the common reservoir within or under the mountain. From a friend of mine who visited the spot three or four days afterwards, I learn that the fountain had ceased, and that the crater increased only a few feet after we left.

"Descending by the stream, we were able to follow it on its south side, as a strong wind was blowing from that direction. Here we found good walking, and could with safety approach within a few feet of the channel. The width of the stream was from twenty to one hundred feet, but its velocity almost incredible. Some of our party thought it one hundred miles per hour. We could not calculate it in any way, for pieces of cold lava thrown into it would sink and melt almost instantly. The velocity certainly seemed as great as that of a railroad car. For eight or ten miles the stream presented a continued succession of cascades, rapids, curves, and eddies, with an occasional cataract. Some of these were formed by the nature of the ground over which it flowed, some by the new lava itself. The stream had built up its own banks on each side, and had added to the depth of its channel by melting at the bottom. The stream flowed more gracefully than water. In consequence of its immense velocity and imperfect mobility, its surface took the same shape as the ground over which it flowed. It therefore presented not only hollows but ridges. In several places for a few feet the course of the stream was an ascent of five to ten degrees, in one instance of twenty-five. Where the turns in the stream were abrupt, the outside of the stream was much higher than the inside. So much was this the case, that the outside sometimes curved over the inside, forming a spiral.

"After arriving at the plain between the mountains, we had so much fog and rain that we could explore but little. We however saw pahoehoe or solid lava forming, and also a-a or clinkers.[1] Pahoehoe was formed mostly by small side streams, and always by shallow streams, which flowed freely but slowly. They were derived generally from the overflowing of the main stream. After flowing for some distance they became cooled at the end, and as there was little pressure from behind, gradually stopped. The little ridges which give the pahoehoe a ropy appearance, were caused by the flowing on of the stream for a little after it had cooled forward, and these are circular because the sides of the stream cool first, while the centre moves on a little further. These streams become solid in a short time, cooling through, and not simply coating over. At a subsequent time during the same flow, another layer of pahoehoe may be formed upon the first, as we saw in several instances.

"The clinkers are always formed by deep streams, and generally by wide ones, which flow sluggishly, become dammed up in front by the cooling of the lava, and in some instances cooled over the top, forming as it were, a pond or lake. As the stream augments beneath, the barriers in front and the crust on the surface are broken up, and the pieces are rolled forward and coated over with melted lava which cools and adheres to them more or less. Then from the force of the melted lava behind and underneath, the stream rolls over and over itself. In this way a bank of clinkers ten to forty feet high, resembling the embankment of a railroad, is formed. Often at the end of the stream no liquid lava can be seen, and the only evidence of motion is the rolling of the jagged rocks, of all sizes, down the front of the embankment. Sometimes the stream breaks through this embankment

[1] Prof. Haskell does not distinguish between a-a and clinkers; they are, however, quite different formations. See above, p. 371.

and flows on for a time until it gets clogged up again, and then the same processes are repeated."[1]

In another letter Prof. Haskell writes under date of June 22d, 1859 : —

"I have just returned from a second visit to the scene of the lava-flood on Mauna Lòa. There is one fact which I observed that I desire to communicate to you. The real source of the flow is about four miles above the two craters, which in February seemed to be the source. From this point down to the two craters, a crack in the mountain can be traced nearly all the way. At first it is no more than two inches in width, but gradually increases to about two feet. At the present time heat can be perceived in the crack within a few feet of the highest point. But little lava has issued from this crack above the two craters. During the first quarter of a mile lava has oozed out in different places a few rods apart, to the amount of three or four cubic feet. Below this point there is a stream, now cold of course, a few rods in width. In this flow, therefore, there is no doubt that there is a continuous crack in the side of the mountain for four miles. How much farther this crack extends down the mountain cannot be ascertained, now at least, for the craters are still sending forth immense volumes of sulphurous vapors, and the stream of lava is still flowing below them. This stream, however, is much smaller than it was in February, and is entirely subterranean for the first twenty-five or thirty miles, except that there are a few holes where the running lava can be seen. In some instances this stream is as much as forty feet below the surface.

"During this trip I went to the top of Mauna Lòa. There is no perceptible action in the crater of Mokuawéowéo. The source of the present flow is probably about 11,000 feet above the level of the sea."[2]

On the 30th of December, 1865, a light was discovered on the summit of Mauna Lòa which rapidly increased in brilliancy, and the whole upper region of the 1865. mountains was bathed in light. The action was wholly confined to the terminal crater of Mokuawéowéo, and although it continued for four months no lateral outbreak took place. During this period the intensity of the volcanic fires varied considerably, sometimes being apparently nearly extinct, and again breaking out with such violence as to illuminate the whole island. As it was winter no one ascended the mountain, and we do not know as yet what the condition of the crater may be since this outburst. It is most remarkable that no lateral streams escaped, and it is probable that the crater has been more or less filled, as is the case in Kilauéa when no stream escapes from the encircling walls.

No sympathy was exhibited in Kilauéa, and although the fires seemed constantly increasing for the last two years, no extraordinary developments took place until some weeks after the summit crater had become extinct. It must not be inferred from this, however, that there is no connection between the two vents. An exactly simultaneous action seldom or never takes place in the adjacent fiery pools of Kilauéa although there is an undoubted connection at a probable depth of less than four hundred feet.[3]

History of Kilauéa.—At what period in the history of Hawaii, Kilauéa first broke forth,

[1] *Silliman's Journal*, [N. S.] vol. xxviii., p. 66. President W. D. Alexander has described this eruption in the "Volcano Supplement to the Pacific Commercial Advertiser," Honolulu, March 26, 1859.

[2] *Silliman's Journal*, [N. S.] vol. xxviii., p. 284.

[3] From letters of Rev. T. Coan to the author.

it is impossible to say. Dana seems to incline to the opinion that some vast rending of Mauna Lòa, similar to that of Háleakala, gave birth to this lateral crater, and accounts for its lasting operation by supposing the rent of immense depth. The other theory, that Kilauéa is coeval with the other members of the Mauna Lòa chain of volcanic peaks, supposes its sides to be too weak to sustain the pressure of a column of lava high enough to overflow the upper rim, and thus increase the height of the mountain by successive discharges. An examination of the lava-streams in the valley between Kilauéa and the slopes of Mauna Lòa, gives the following result: the valley is deeper than the ancient black ledge of the crater, narrow, and the wall towards Kilauéa is much broken by rents, some of which have taken place in the last two years, and the layers which have run over Kilauéa pass under those from Mauna Lòa, although the latter seem of equal antiquity. Again, in looking for traces of a rupture like that on Máui, or like the smaller one on the south-western side of this same mountain, mentioned in the description of Ka-ù, no signs of dislocation can be found at all commensurate with the supposed size of the fissure; the mountain is quite as even and regular on this side as on the others.

Whether Kilauéa was formed before or after Mauna Lòa its action has been generally independent of the summit crater, and while an eruption has been taking place on the top, Kilauéa, ten thousand feet below, and only sixteen miles distant, exhibited no signs of sympathy. A history of the recorded eruptions will make this independent action of the two volcanoes more evident. The first of which any authentic account has been

1789. preserved took place in 1789, and was observed by many natives who were marching to battle under the chief Keoùa. On their way from Hìlo to Ka-ù they encamped by the volcano.[1] "In the night a terrific eruption took place, throwing out flame, cinders, and even heavy stones to a great distance." Thunder and lightning accompanied this outburst, and the terrified natives dared not proceed. But on the second and third night similar disturbances took place, and they resolved to move on, separating for safety into three companies. The party in advance had not proceeded far, "before the ground began to shake and rock beneath their feet, and it became quite impossible to stand. Soon a dense cloud of darkness was seen to rise out of the crater, and almost at the same instant the electrical effect upon the air was so great that the thunder began to roar in the heavens, and the lightning to flash. It continued to ascend and spread abroad until the whole region was enveloped and the light of day was entirely excluded. The darkness was the more terrific, being made visible by an awful glare from streams of red and blue light variously combined, that issued from the pit below, and being lit up at intervals by the intense flashes of lightning from above. Soon followed an immense volume of sand and cinders which were thrown in high heaven and came down in a destructive shower for many miles around. Some few persons of the forward company were burned to death by the sand and cinders, and others were seriously injured. All experienced a suffocating sensation upon the lungs and hastened on with all possible speed.

"The rear body, which was nearest the volcano at the time of the eruption, seemed to suffer the least injury, and after the earthquake and shower of sand had passed over, hastened forward to escape the dangers which threatened them, and rejoicing in mutual congratulations that they had been preserved in the midst of such imminent peril. But what was their surprise and consternation, when on coming up with their comrades of the centre

[1] *History of the Sandwich Islands*, by Sheldon Dibble, Lahainalùna, 1843, p. 65.

party, they discovered them all to have become corpses. Some were lying down, and others were sitting upright, clasping with dying grasp their wives and children, and joining noses (their form of expressing affection) as in the act of taking a final leave. So much like life they looked, that they at first supposed them merely at rest, and it was not until they had come up to them and handled them, that they could detect their mistake. Of the whole party, including women and children, not one survived to relate the catastrophe that had befallen their comrades. The only living being they found, was a solitary hog. In these perilous circumstances the surviving party did not even stay to bewail their fate, but leaving their deceased companions as they found them, hurried on, and overtook the company in advance."

On their return after a week or ten days, they found the bodies entire and exhibiting no signs of decay except a hollowness of the eyes. They were never buried, and a missionary who collected a part of the account from the natives who marched with Keoùa, saw a human skull lying in the black volcanic sand of this neighborhood. It is said by some who saw the corpses that, although never deeply burned, they were thoroughly scorched, and this will perhaps account for their preservation for so many days.

This eruption surpassed any subsequent one, and was of a totally different nature. No lava is mentioned, but an immense amount of sand and scoriæ, with volumes of steam and sulphurous vapor. The description at once reminds us of the eruption of Vesuvius in 79; the same black, lofty column of smoke, lightnings, and destructive showers of sand such as overwhelmed Pompeii and Herculaneum. Could it have marked a renewal of activity after a long rest, and were the scoriæ the remains of the long-cooled crust at the bottom of the crater? South and west of Kilauéa where the sand deposits are quite extensive, the whole ground is cracked with earthquake throbs. These rents are sometimes filled with the black sand, and sometimes, especially near Ponahohòa, with lava.[1] It seems probable that from these cracks came the steam and vapor so destructive to the army, as those nearer the crater did not suffer from them. The prevailing trade-winds have carried all the ejections of this eruption to the south-west of the crater, and no sand of similar appearance is found on the windward side. The Ponahohòa region seems to overlie some fissure, or at least a weak part of the volcanic dome, as the earthquakes are usually quite severe here, cracks are frequent, and even lava has been ejected, although there are no signs of the existence of a volcano distinct from Kilauéa. More probably it is over the line of a subterranean lava-stream, and the facts mentioned by the Rev. William Ellis, who visited the place in 1823, seem to corroborate this view. He saw a deep chasm which had opened several months before, and was still emitting vapors. Black lava was spattered on the bushes and rocks in the neighborhood, and at the same time there is every reason to believe that the lavas of Kilauéa were finding an outlet.

The appearance of Kilauéa itself as described by Mr. Ellis, who was the first to publish an account of it, was quite different from its present condition.[2] It was 1823.
evidently in an unfilled state, and we must infer that it was emptying itself, as the action was much diminished the next year. It may be allowable then to consider 1823 as the date of an eruption although no stream of lava, if we except the traces at Ponahohòa, appeared above ground. The volcano discharged as usual by a lateral rent, the side walls

[1] See plate in *A Tour through Hawaii*, by Rev. William Ellis. London, 1827, p. 203.

[2] Mr. Ellis visited Kilauéa, August 1, 1823.

of the dome yielding before the pressure of the enclosed lava, and quietly allowing the passage of the molten torrent to the sea. Ellis's description is as follows: —

"Immediately before us yawned an immense gulf, in the form of a crescent, upwards of two miles in length, about a mile across, and apparently eight hundred feet deep. The bottom was filled with lava, and the south-west and northern parts of it were one vast flood of liquid fire, in a state of terrific ebullition, rolling to and fro its fiery surge and flaming billows. Fifty-one craters of varied form and size rose like so many conical islands from the surface of the burning lake. Twenty-two constantly emitted columns of gray smoke, or pyramids of brilliant flame, and many of them at the same time vomited from their ignited mouths streams of florid lava which rolled in blazing torrents down their black indented sides into the boiling mass below.

"The sides of the gulf before us were perpendicular for about four hundred feet, when there was a wide horizontal ledge of solid black lava of irregular breadth, but extending completely round. Beneath this black ledge the sides sloped to the centre, which was, as nearly as we could judge, three or four hundred feet lower. It was evident that the crater had been recently filled with liquid lava up to this black ledge, and had, by some subterranean canal, emptied itself into the sea, or inundated the low land on the shore. . . . Between nine and ten [in the evening], the dark clouds and heavy fog that since the setting of the sun had hung over the volcano gradually cleared away. The agitated mass of liquid lava, like a flood of melted metal, raged with tumultuous whirl. The lively flame that danced over its undulating surface tinged with sulphureous blue, or glowing with mineral red, cast a broad glare of dazzling light on the indented sides of the insulated craters whose bellowing mouths, amidst rising flames, shot up at frequent intervals with loudest detonations, spherical masses of fusing lava, or bright ignited stones. . . . [In passing along the eastern edge of the crater], we entered several small craters that had been in vigorous action but a short period before, marks of very recent fusion presenting themselves on every side. Their size and height was various, and many which from the top had appeared insignificant as mole hills, we now found to be twelve or twenty feet high. The outsides were composed of bright shining lava, heaped up in piles of most singular form. The lava on the inside was of a light or dark-red color with a glazed surface, and in several places, where the heat had evidently been intense, we saw a deposit of small and beautifully white crystals. . . . In the neighborhood we saw several large rocks of a dark gray color weighing probably from one to four or five tons, which although they did not bear any marks of fire, must have been ejected from the great crater during some violent eruption, as the surrounding rocks in every direction presented a very different appearance. They were hard, and exhibited, when fractured, a glimmering and uneven surface.[1] . . . As we travelled on from this spot, we unexpectedly came to another deep crater, nearly half as large as the former. The native name of it is Kilauéa-iki, or Little Kilauéa. It is separated from the large crater by an isthmus nearly one hundred yards wide. Its sides were covered with trees and shrubs, but the bottom was filled with lava, either fluid or scarcely cold, and probably supplied by the great crater, as the trees on its sides showed that it had remained many years in a state of quiescence."[2]

The next year Kilauéa is described as follows: —

[1] Similar rocks are now found in ridges through the crater. Their composition is given below.

[2] Rev. William Ellis, *loc. cit.* p. 224.

"From the time we arrived within two miles of the crater, we had the smoke arising from it directly in our faces, attended with a sulphureous stench. The wind 1824.
was very strong and brought along with it fine particles of sand so that I found it necessary to draw my hat as close as possible over my eyes in order to preserve them, carrying my head at the same time pretty low. The travelling was also difficult from the sand which covered the smooth stones on which we had before walked. Into this sand our feet sunk six or eight inches at every step. We however sometimes found the sand sufficiently hard and compact to bear us up. . . . We reached several large crevices from which smoke was issuing at a distance of five miles from the crater. Continuing to advance towards the crater our attention was arrested by a hissing noise like that of the blowing of a furnace, except that it was irregular, the noise being sometimes very low, and then again exceedingly loud. The smoke in which we were now enveloped became so dense that we could see only a small distance before us. . . . We had made the volcano at the south-west end, and we now proceeded round the eastern side hoping to be soon freed from the steam or smoke, which, being condensed by the wind, was falling upon us like rain. . . . At the distance of two hundred and fifty or three hundred feet below us was a level platform which appeared to have been formed by the falling in of the bank of the crater. This platform, I believe, extends nearly around the whole of the crater which is supposed to be nearly six miles in circumference. I had little difficulty in descending to this platform. From the side where I descended it extends nearly fifteen rods towards the centre of the crater, where there is another descent of two hundred and fifty or three hundred feet. Down this I proceeded, though not without danger, it being in most places perpendicular, and nearly so where I descended. Many of the stones also on which it was necessary to step were loose. . . . I had now reached the ancient bed of the volcano, having, as I supposed, descended six hundred feet. The surface of the lava was smooth though not level, sometimes rising in heaps like cocks of hay, and broken by innumerable fissures crossing each other in various directions.

"This lava was of a deep black color, exceedingly porous, and as light as a pumice-stone. The steam was constantly issuing from the crevices, and was so hot that I could not hold my hand in it for a moment. On this bed of lava I walked eight or ten rods towards the centre of the crater, when I came to another descent of two or three hundred feet, the volcano having sunk thus far below its ancient bed. The lower bed appeared much like the one on which I stood, but from various parts of it not only smoke, but flames of fire were issuing. The appearance of these small craters where the fire was bursting out, attended with a horrid noise, was indeed awfully grand, but I was disappointed in not finding this lower bed a mass of liquid fire. About a year since, when several of our brethren were making the tour of this island, this lower bed of lava was in a liquid state. The surface has now become hard, and I have no doubt would have supported my weight could I have descended to it. This I wished to do, but I looked in vain for a place where I might descend, the sides being in most places shelving over or perpendicular. . . . I proceeded along to the base of the sulphur mountain to collect specimens to carry home. It was in those places from which the smoke was issuing that I found the sulphur most pure, and formed into beautiful crystals."[1]

[1] The writer has been permitted to extract the above account from an unpublished *Journal* of E. Loomis, who was connected with the American Mission, and visited the volcano on the 16th of June 1824.

1825. The next year, July 28th, 1825, Kilauéa was visited by the Rev. C. S. Stewart, who describes its appearance as follows:[1] —

"About midway from the top a ledge of lava, in some places only a few feet, in others many rods wide, extends entirely round, at least so far as an examination has been made, forming a kind of gallery to which you can descend in two or three places, and walk as far as the smoke settling at the south end will permit. . . . The gulf below contains probably not less than sixty, — fifty-six have been counted, — smaller conical craters, many of which are in constant action. The tops and sides of two or three of these are covered with sulphur of mingled shades of yellow and green. With this exception, the ledge and every thing below it are of a dismal black. The upper cliffs on the northern and western sides are perfectly perpendicular, and of a red color, everywhere exhibiting the seared marks of former powerful ignition. Those on the eastern side are less precipitous, and consist of entire banks of sulphur of a delicate and beautiful yellow. The south end is wholly obscured by smoke which fills that part of the crater and spreads widely over the surrounding horizon. . . . Two or three of the small craters nearest to us were in full action, every moment casting out stones, ashes, and lava, with heavy detonations, while the irritated flames accompanying them glared widely over the surrounding obscurity. . . . The great seat of action, however, seemed to be at the south-western end. . . . Rivers of fire were seen rolling in splendid corruscations among the laboring craters, and on one side a whole lake whose surface constantly flashed and sparkled with the agitation of contending currents. . . . At an inconsiderable distance from us was one of the largest of the conical craters whose laborious action had so impressed us during the night. On reaching its base, we judged it to be one hundred and fifty feet high — a huge, irregularly shapen, inverted funnel of lava, covered with clefts, orifices, and tunnels, from which bodies of steam escaped with deafening explosion, while pale flames, ashes, stones, and lava were propelled with equal force and noise from its ragged and yawning mouth. . . . Leaving the sulphur banks on the eastern side behind us, we directed our course along the northern part to the western cliffs. As we advanced, these became more and more perpendicular, till they presented nothing but the bare and upright face of an immense wall, from eight to ten hundred feet high, on whose surface huge stones and rocks hung — apparently so loosely as to threaten falling, at the agitation of a breath. In many places a white curling vapor issued from the sides and summit of the precipice; and in two or three places streams of clay colored lava, like small waterfalls, extending almost from the top to the bottom, had cooled evidently at a very recent period."

Lieutenant Malden, who accompanied Mr. Stewart, made a sketch of the crater,[2] and calculated the height of the upper cliff from the black ledge, at nine hundred feet, making the whole depth of the crater fifteen hundred feet; and the circumference of the crater at its bottom, from five to seven miles, and at its top from eight to ten miles. On the evening of the 29th, after terrific noises and tremblings of the ground, "a dense column of heavy black smoke was seen rising from the crater directly in front of us — the subterranean struggle ceased — and immediately after, flames burst from a large cone, near which we had been in the morning, and which then appeared to have been long inactive. Red-hot stones, cinders, and ashes, were also propelled to a great height with immense violence; and shortly after the molten lava came boiling up, and flowed down the sides of the cone, and over the

[1] *Journal* by C. S. Stewart, p. 374.

[2] See the plan of Kilauéa, Plate XV.

surrounding scoriæ, in two beautifully curved streams." At the same time a whole lake opened over an extent two miles in circumference.

In December of the same year Rev. A. Bishop found the crater much fuller than when he visited it with Mr. Ellis in 1823. There were many cones from fifty to one hundred feet high on a surface about four hundred feet higher than the bottom of the crater two years before. There were lakes boiling actively, and "every now and then sending forth a gust of vapor and smoke with great noise.[1] The natives remarked that after rising a little higher the lava will discharge itself, as formerly, towards the sea, through some aperture underground."

In the early part of October 1829, the Rev. C. S. Stewart again visited the crater. 1829.
He found the lower pit filled up more than two hundred feet; many of the cones had disappeared, and there was much more fire at the northern end. He thus describes two cones which he examined. "They were in the neighborhood of each other — each about twenty feet in height, not more than sixty in circumference at the base, and tapering almost to a point at the top — being in fact two immense hollow columns formed by successive slight overflowings of lava, cooling as it rolled down, into irregular flutings, ornamented with rude drops and pendants, and long tapering stalactites. Though the ragings beneath must have been intense, from the tremendous roar within, the irresistible force and deafening hiss with which the steam rushed from every opening, and from the flames which flashed up, followed by lava white with an intensity of heat, still the incrustation of scoriæ im mediately around seemed firm, and was less hot, than in many other places; admitting not only of our coming close to the sides of the cone, but also of clambering some feet up them, till we could run our canes into the orifices at the top, and withdraw, with their burning ends, red-hot lava, on which we readily made impressions. Pélé did not seem well pleased with this familiarity, however; even the slightest touch with our sticks against the molten lava, produced an increased rush and roar from below, with an angry spitting of the fiery matter high in the air around us."[2]

Four years after, an eruption took place simultaneously with one from the summit 1832.
of Mauna Lòa. Unfortunately we have no account from any eye-witness. In September 1832, the Rev. J. Goodrich visited Kilauéa, and describes the appearance of the emptied crater. "The lavas had previously risen fifty feet above the black ledge, but were now more than four hundred feet below this level, and the action seemed confined to the Halemáuman at the south end. In January an earthquake had rent in twain the wall between Kilauéa and Poli-o-Keàwe,[3] the large crater on the east, producing seams from a few inches to several yards in width, from which the region between the two craters was deluged with lava."[4]

This outbreak on the wall was very remarkable, rising as it did in a strip of land four hundred yards wide bounded on either side by precipices between two and three hundred feet high. Before this time, Poli-o-Keàwe had long been free from volcanic action, and its sides were wooded to the bottom. The stream issued from several rents south of the centre of the isthmus and above the lowest part, flowed toward the north a few yards to the lowest part, and then ran east and west into the two craters in a stream a hundred feet wide but quite shallow; indeed the quantity of lava was so small, that its eruption is hardly more

1 *Missionary Herald*, vol. xxiii., p. 53.
2 *A Visit to the South Seas*, vol. ii., p. 93.
3 The same called by Ellis Kilauéa-iki.
4 *Silliman's Journal*, [N. S.] vol. xxv., p. 199.

wonderful than the action of slender cones as described by Mr. Stewart. Where the subterranean discharge which emptied the crater, reached the sea, is not known.

1834. Mr. David Douglass was at Kilauéa in January 1834, and measured the depth of the pit at one thousand feet. A lake of boiling lava at the north end was three hundred and nineteen yards in diameter. The Halemáumau was much in the condition as described by Mr. Ellis.[1]

1838. On the 8th of May 1838, Captains Chase and Parker visited Kilauéa, and their description has been published with a sketch of the crater.[2] The lavas had again nearly reached the black ledge, and all over a surface of four square miles were cones and lakes of fire; twenty-six of the former were counted, eight of which were ejecting cinders and red-hot lava. Six small lakes were boiling violently, becoming crusted over, cracking, and again boiling. On the Halemáumau was an island which the lava was not seen to overflow. The remarkable oscillations in the heat, remarked by all visitors, seem to have taken place on this occasion with more than the usual rapidity. As they were looking at one of the lakes which was boiling violently, they say: "After a few minutes, the violent struggle ceased, and the whole surface of the lake was changed to a black mass of scoriæ; but the pause was only to renew its exertions; for, while they were gazing at the change, suddenly the entire crust which had been formed, commenced cracking, and the burning lava soon rolled across the lake, heaving the coating on its surface like cakes of ice upon the ocean surge." As they left the crater, nearly a quarter of the floor gave way, forming a vast pool of liquid lava.

Count Strzelecki, in the same year, estimates the size of five of the lakes at about five thousand seven hundred square yards, and they were almost at the level of the great area. The Halemáumau was encircled by a wall of scoriæ fifty yards high, and covered an area of three hundred thousand square yards.[3]

1839. Captain John Shepherd was at the crater September 16th, 1839. The Halemáumau was estimated at a mile in length and half a mile in breadth, and flowed over in some places "leaving ridges of scoriæ on the northern side." [4]

It took nine years for Kilauéa to fill up after the eruption of 1823; and for eight years the process had been continued until the lava had reached a point nearly a hundred feet above the black ledge which seems to be about the limit of pressure the walls of the mountain will bear. The force tending to rupture the mountain may be readily calculated, assuming the pressure of every twelve feet of lava to be fifteen pounds to the square inch; and as the crater is usually emptied to a depth of four hundred feet we have a pressure of five hundred pounds to the square inch. It must be remembered that the mountain wall is by no means solid and compact, and although successive discharges may strengthen some volcanic mountains, here the effect seems to be quite the contrary, owing to the extreme fluidity of the lava which runs off, leaving tunnels and caverns instead of solid interlacing dykes; consequently the discharges usually follow the same direction.

Kilauéa, then, was ready to break out, and in 1840 the most extensive eruption recorded took place.

1840. Rev. Titus Coan thus describes the eruption of 1840 in a letter dated September 25th, 1840.

[1] *Journal of the Royal Geographical Society*, vol. iv.
[2] *Silliman's Journal*, [N. S.] vol. xl., p. 117.
[3] *Hawaiian Spectator*, vol. i., p. 435.
[4] *Athenæum*, November 14, 1840.

"For several years past the great crater of Kilauéa has been rapidly filling up by the rising of the superincumbent crust, and by the frequent gushing forth of the molten sea below. In this manner the great basin below the black ledge, which has been computed from three to five hundred feet deep, was long since filled up by the ejection and cooling of successive masses of the fiery fluid. These silent eruptions continued to occur at intervals, until the black ledge was repeatedly overflowed, each cooling and forming a new layer from two feet thick and upwards, until the whole area of the crater was filled up, at least fifty feet above the original black ledge, and thus reducing the whole depth of the crater to less than nine hundred feet. This process of filling up continued till the latter part of May 1840, when, as many natives testify, the whole area of the crater became one entire sea of ignifluous matter, raging like old ocean when lashed into fury by a tempest. For several days the fires raged with fearful intensity, exhibiting a scene awfully terrific. The infuriated waves sent up infernal sounds, and dashed with such maddening energy against the sides of the awful cauldron, as to shake the solid earth above, and to detach huge masses of overhanging rocks, which, leaving their ancient beds, plunged into the fiery gulf below. So terrific was the scene that no one dared to approach near it, and travellers on the main road, which lay along the verge of the crater, feeling the ground tremble beneath their feet, fled and passed by at a distance. I should be inclined to discredit these statements of the natives, had I not since been to Kilauéa and examined it minutely with these reports in view. Every appearance however, of the crater confirms these reports. Every thing within the cauldron is new. Not a particle of lava remains as it was when I last visited it. All has been melted down and recast. . . . I will now give a short history of the eruption itself.

"On the 30th of May, the people of Púna observed the appearance of smoke and fire in the interior, a mountainous and desolate region of that district. Thinking that the fire might be the burning of some jungle, they took little notice of it until the next day, Sabbath, when the meetings in the different villages were thrown into confusion by sudden and grand exhibitions of fire, on a scale so large and fearful as to leave them no room to doubt the cause of the phenomenon. The fire augmented during the day and night; but it did not seem to flow off rapidly in any direction. All were in consternation, as it was expected that the molten flood would pour itself down from its height of four thousand feet to the coast, and no one knew to what point it would flow, or what devastation would attend its fiery course. On Monday, June 1st, the stream began to flow off in a northeasterly direction, and on the following Wednesday, June 3d, at evening, the burning river reached the sea, having averaged about half a mile an hour in its progress. The rapidity of the flow was very unequal, being modified by the inequalities of the surface, over which the stream passed. Sometimes it is supposed to have moved five miles an hour, and at other times, owing to obstructions, making no apparent progress except in filling up deep valleys, and in swelling over or breaking away hills and precipices.

"But I will return to the source of the eruption. This is in a forest, and in the bottom of an ancient wooded crater, about four hundred feet deep, and probably eight miles east of Kilauéa. The region being uninhabited and covered with a thicket, it was some time before the place was discovered; and up to this time, though several foreigners have attempted it, no one, except myself, has reached the spot. From Kilauéa to this place the lava flows in a subterranean gallery probably at the depth of a thousand feet, but its course can be distinctly traced all the way, by the rending of the crust of the earth into innumerable fissures, and by the emission of smoke, steam, and gases. The eruption in this old crater is small, and from this place the stream disappears again for the distance of a mile or two when the lava again gushes up and spreads over an area of about fifty acres. Again it passes underground for two or three miles, when it reappears in another old wooded crater, consuming the forest and partly filling up the basin. Once more it disappears, and flowing in a subterranean channel, cracks and breaks the earth, opening fissures from six inches to ten or twelve feet in width, and sometimes splitting the trunk of a tree so exactly that its legs stand astride at the fissure. At some places it is impossible to trace the subterranean stream on account of the impenetrable thicket under which it passes. After flowing underground several miles, perhaps six or eight, it again broke out like an overwhelming flood, and sweeping forest, hamlet, plantation, and every thing before it, rolled down with resistless energy to the sea, where, leaping a precipice of forty or fifty feet, it poured itself in one vast cataract of fire into the deep below, with loud detonations, fearful hissings, and a thousand unearthly and indescribable sounds. Imagine to yourself a river of fused minerals, of the breadth and depth of Niagara, and of a deep gory red, falling in one emblazoned sheet, one raging torrent, into the ocean. . . . The atmosphere in all directions was filled with ashes, spray, gases, etc.; while the burning lava as it fell into the water was shivered into millions of minute particles, and, being thrown back into the air fell in showers of sand on all the surrounding country. The coast was extended into the sea for a quarter of a mile, and a pretty sand beach, and a new cape were formed. Three hills of scoriæ and sand were also formed in the sea, the lowest about two hundred, and the highest about three hundred, feet.

"For three weeks this terrific river disgorged itself into the sea with little abatement. Multitudes of fishes were killed, and the waters of the ocean were heated for twenty miles along the coast. The breadth of the stream where it fell into the sea, is about half a mile, but inland it varies from one to four or five miles in width, conforming itself, like a river, to the face of the country over which it flowed. The depth of the stream will probably vary from ten to two hundred feet, according to the inequalities of the surface over which it passed. During the flow night was converted into day on all eastern Hawaii; the light was visible for more than one hundred miles at sea; and at the distance of forty miles fine print could be read at midnight.

"The whole course of the stream from Kilauéa to the sea is about forty miles. The ground over which it flowed descends at the rate of one hundred feet to the mile. The crust is now cooled, and may be traversed with care, though scalding steam, pungent gases, and smoke are still emitted in many places. In pursuing my way for nearly two days over this mighty smouldering mass, I was more and more impressed at every step with the wonderful scene. Hills had been melted down like wax; ravines and deep valleys had been filled; and majestic forests had disappeared like a feather in the flames. On the outer edge of the lava, where the stream was more shallow and the heat less vehement, and where of course the liquid mass cooled soonest, the trees were mowed down like grass before the scythe, and left charred, crisp, smouldering, and only half consumed. As the lava flowed around the trunks of large trees on the outskirts of the stream, the melted mass stiffened and consolidated before the trunk was consumed, and when this was effected, the top of the tree fell, and lay unconsumed on the crust, while the hole which marked the place of the trunk remains almost as smooth and perfect as the calibre of a cannon. These holes are innumerable, and I found them to measure from ten to forty feet deep, but, as I remarked before, they are in the more shallow part of the lava, the trees being entirely consumed where it was deeper. During the flow of this eruption the great crater of Kilauéa sunk about three hundred feet, and her fires became nearly extinct, one lake only out of many being left in the mighty cauldron. This open lake is at present intensely active, and the fires are increasing, as is evident from the glare visible at our station, and from the testimony of visitors. During the early part of the eruption slight and repeated shocks of earthquake were felt, for several successive days, near the scene of action. These shocks were not noticed at Hilo. Through the directing hand of a kind Providence no lives were lost, and but little property was consumed during this amazing flood of fiery ruin.

"During the progress of the descending stream, it would often fall into some fissure, and forcing itself into apertures, and under massive rocks, and even hillocks and extended plats of ground, and lifting them from their ancient beds, bear them with all their superincumbent mass of soil, trees, etc., on its viscous and livid bosom, like a raft on the water. When the fused mass was sluggish, it had a gory appearance like clotted blood, and when it was active, it resembled fresh and clotted blood mingled and thrown into violent agitation. Sometimes the flowing lava would find a subterranean gallery diverging at right angles from the main channel, and pressing into it would flow off unobserved, till meeting with some obstruction in its dark passage, when, by its expansive force, it would raise the crust of the earth into a dome-like hill of fifteen or twenty feet in height, and then bursting this shell, pour itself out in a fiery torrent around. A man who was standing at a considerable distance from the main stream, and intensely gazing on the absorbing scene before him, found himself suddenly raised to the height of ten or fifteen feet above the common level around him, and he had but just time to escape from his dangerous position, when the earth opened where he had stood, and a stream of fire gushed out." [1]

The small crater where the lava first appeared is called Ararè, and is about six miles east of Kilauéa, in the dense forest. The natives say that the lava rose in this crater about three hundred feet, and then sunk again when the fissure opened below, and at the present time there are evident proofs of this on the crater walls. The line the stream seems to have followed passes through a high hill (seen in the view of the Deep Crater Fig. 44) thus just avoiding this large pit where it might be supposed the resistance would be least, but the hill is undoubtedly hollow, being a cone from which the lava has been emptied, and the cavity beneath it was perhaps larger than that of the pit crater.

The elevation of the place where the lava finally reached the surface is given by Wilkes at 1244 feet, and it is twenty-seven miles from Kilauéa, twenty-one from the first outbreak, and twelve from the shore at Nanawálie. The sand-hills thrown up at this place were found to be one hundred and fifty, and two hundred and fifty feet high, eight months after their formation. At present they are not a third of this height, as the sea has rapidly removed the loose material of which they are composed. There seems to be no reason for supposing that any fissure beneath these hills opening to the interior reservoirs of lava existed, as the height from which the lava reached the sea is amply sufficient to account for their formation, and they do not at present correspond with the other tufa cones on the islands.

In November of the same year, when visited by Prof. Dana, the lava was still hot in many places, a few feet below the surface. Small sulphur-banks, with deposits of alum and other salts, were met with in several places.[2]

[1] *Missionary Herald*, vol. xxxvii., p. 283.

[2] *Geology United States Exploring Expedition*, p. 190

The lava of this eruption closely resembles that in the walls of Aliapaakaì on Oáhu, and like that contains a very large proportion of chrysolite, in some places nearly one half, and in quite large grains. No similar lava is found in Kilauéa, but chrysolitic lava has issued in several streams from Mauna Kéa in ancient times, and also perhaps from Mauna Lòa, if we suppose the large deposits of this lava occasionally found along the coast near Hìlo to have proceeded from this mountain.

In November of the same year, when visited by Prof. Dana, the lava had fallen three hundred and forty feet below the black ledge, or nearly one thousand feet below the highest wall, and only three pools of lava were in action. The Halemáumau was fifteen hundred feet long and a thousand feet wide. The black ledge, three hundred and forty feet from the bottom, was from one to three thousand feet wide, and extended completely around the crater. No flames were visible, and there was but little noise.[1]

1841. In December, and January 1841, Dr. Pickering describes several considerable variations in the surface of the Halemáumau, a hundred feet or more. On the 17th of January, two of the pools discharged large quantities of lava over the bottom of the crater.[2]

1842. The next February, Mr. Coan writes as follows: "When within four or five rods of the great lake, unaware of our near proximity to it, we saw directly before us a vast area of what we had supposed to be solid lava moving off to the right and left. We were at first a little startled, not knowing but all was about to float away beneath us, especially as the lavas for a mile back were almost insupportably hot, and gases and steam were escaping from numerous openings. On looking again, we perceived that the whole surface of the lake was from six to fifteen feet above the level of the surrounding lava, although at my last visit, it was from sixty to seventy feet below. Within six feet of this embankment we could see nothing of the lake, and in order to examine it we climbed the precipice some fifty feet. The explanation of this strange condition of things, is this: When the liquid contents of the lake had risen to a level with the brim, there was a constant and gradual boiling over of the viscid mass, but in quantities too small to run off far. Consequently, it solidified on the margin, and thus formed the high rim which confined the lavas. Twice, or at two points while we were there, the liquid flood broke through the rim, and flowed off in a broad, deep channel which continued its flow until we left the volcano. The view was a new one, and thrilling beyond description."[3]

1844. In July, Mr. Coan saw the large lake overflow on every side, spreading over the whole southern end of the crater to the base of the black ledge on either side, and wholly concealing the outlines of the cauldron. Two deep fissures opened under the ledge on either side, nearly encircling that part of the crater, and one of these was two hundred feet deep. Soon these yawning gulfs were filled with the overflow of the Halemáumau, and in one place the lava "fell in a cascade of fifty feet, producing a scene of terrific sublimity."

1846. In a letter dated June 25th, 1846, Mr. Coan states that "the great lake is intensely active most of the time. The repeated overflowings have elevated the central parts of the crater four or five hundred feet since 1840, so that some points are now more elevated than the black ledge."

The Rev. C. S. Lyman visited Kilauéa twice this year, and we find from his description

[1] *Loc. cit.* p. 171. [2] *Narrative of the United States Exploring Expedition*, vol. iv., p. 178. [3] *Loc. cit.* p. 178.

that several changes of importance had taken place. The long ridge of blocks of compact lava, like the upper wall which extends at intervals nearly around the northern edge of the crater, had then formed. He says: "This ridge rose on its outer or eastern face often to the height of fifty or one hundred feet, especially towards the south, where it approached the great lake; and generally it left a space or canal as it has been called, between it and the ledge [black ledge of Prof. Dana] several rods in width, and in some places forty or fifty feet in depth." The canal mentioned is the same one into which Mr. Coan saw the lava flow in 1844. The lake at the southern end was still surrounded by a rim of lava, and bounded on the north-east by a high plateau, — the raised floor of the crater. There was no other lake or pool of lava visible. A curious dome, corresponding to the "hornitos," described by Humboldt in the malpays of Jorullo, was observed about a mile north of the great lake. It was ten or twelve feet high, its walls not "more than a foot thick, and through two openings, the one a foot and the other half a foot in diameter, the interior was revealed of a glowing white heat, and by throwing pieces of lava into these orifices they were seen to fall into the pasty semifluid mass ten or fifteen feet below. This furnace was in full blast six weeks after."[1]

Mr. Coan, in a letter dated December 7th, 1846, says: "Visited the volcano a few days ago. Found the lake full and active. Dipped up the molten lava with our canes." So that the lava must have risen ten or twenty feet in the few months since Mr. Lyman's visit, when the lava was that depth below the rim.

Mr. Coan again writes in a letter dated January 1851: "My next visit to the crater was in July 1847, in company with Captain (late Admiral) Dupont and several officers 1847. of the United States ship Cyane. No essential changes had occurred in the bottom of the volcano during this interim, except that the great lake had filled up, had overflowed a considerable area around its rim, was still full and in an active state. The boiling of the lava was intense around most of its circumference, and at many points over its surface. Access to the red-rolling fusion was comparatively easy, so that by carefully watching and dodging its fiery jets we could dip up its viscid matter with sticks or ladles. Silent and successive overflowings took place from time to time during this year, considerably elevating all the area in the vicinity of Halemáumau, but not affecting the other and larger portions of the crater. I think it was about the beginning of 1848, that the great lake was first noticed as crusted over with a thick stratum of lava, and this stratum was soon 1848. raised into a dome some two or three hundred feet high over the whole lake; traversed here and there by rents and fissures, and studded by an occasional cone. Occasionally the visitor, or the passing traveller, would descry, through these fissures, the glowing of the subterranean fires, and now and then the gory mass would be pressed sluggishly through these chasms or driven up with more force through the several chimneys, apertures, or orifices of the dome. These eruptions rolled in heavy and irregular streams down the sides of the dome, spreading over its surface or cooling at its base. Thus the dome as it now exists, has been formed by the compound action of upheaving forces from beneath, and of eruptions from its openings forming successive layers upon its external surface. During most of this year, however, an extraordinary *inactivity* prevailed throughout the crater. During the summer and autumn when I was at Kilauéa, there was no fire to be seen even in

[1] *Silliman's Journal of Science* [N. S.], vol. xii., p. 75. From a manuscript map prepared by Mr. Lyman, I find the "ridge" occupied the same position as at present. See the Plan of Kilauéa, Plate XV.

the night. Old Vulcan seemed to have forsaken his furnace, buried his fires, and retired to his deep, dark caverns, leaving his awful forge surrounded with smouldering masses of scoriæ and slag. At the time of my visit in August, the great dome was so elevated as almost to overtop the lower parts of the outer walls of Kilauéa and look out upon the surrounding country.

1849. "In April and May 1849, travellers upon the borders of Kilauéa were startled by explosions and detonations from cones on the great dome. A party lodging in the hut on the upper banks were greatly terrified during one whole night, by hissings, bellowings, and sharp and loud detonations, sometimes like the discharge of whole ranks of musketeers, sometimes like field artillery, and sometimes like awful deep-toned thunder, roaring and reverberating around the adamantine walls of the dark cavern. These bellowings were repeated hourly through the night, and were attended by a brilliant column of red-hot lava thrown perpendicularly from an orifice in the apex of the dome to the height of some fifty or sixty feet. At other times red-hot stones were projected with great force into the air and sent whizzing like fiery meteors through the gloom of night. As the glow of this scene a little abated, a stream of burning lava was disgorged from the orifice of a lateral cone on the ridge of the dome, flowing down to its base and winding along upon the dark substratum like a fiery serpent. Fire was seen through some of the fissures in the dome, and nearly the whole bottom of Kilauéa was quivering and cracking with heat; so much so, that travellers feared to descend into any part of the crater.

"Since the time just mentioned no remarkable phenomena have been noticed in the crater. It has been for the most part in a quiescent state, with more or less steam and smoke, and occasionally opening a small red eyelid, or letting loose a few fire-flies upon the wings of the night.[1]

1850. "During December of 1850, the smoke and steam are said to have much increased; and the occasional throe of an earthquake indicates that all subterranean action has not ceased. The sulphur beds remain much as formerly, except, perhaps, that the bank within the crater has less heat and activity, and the one above, or near the hut, has a little increase of heat.

1851. "There is now one cone feebly active at a little distance from the dome in the crater. Those *on* the dome are inactive."[2]

1852. Mr. Coan, after a visit to Kilauéa the next year, writes under date of July 30th: "I had visited Kilauéa in March and found the action in the crater much increased. On this occasion the action was still more intense. The great dome, one mile and a half in circuit and several hundred feet high, has now lost its keystone, and the massive arch is fallen in. The orifice on the summit is two hundred feet in diameter, and through this orifice you look directly upon the raging fire below. On one side the dome is rent from the base to the summit, and through this fissure smoke and lava pass off from the boiling cauldron.

"This fiery lake, so long concealed by the ponderous dome, is gradually rising and lifting and rending the superincumbent strata of which the great dome is composed, and threaten-

[1] In a letter from Lieut. Henry Eld who accompanied the United States Exploring Expedition in 1840, and again revisited the crater this year, we find that the bottom was much raised, the lava had subsided in the great lake and seemed nearly extinguished. *Silliman's Journal* [N. S.], vol. ix., p. 362.

[2] *Silliman's Journal* [N. S.], vol. xii., p. 80

ing at no distant day to engulf the whole overhanging mass within its burning bowels. Aside from this increased action within the dome, no important changes have occurred in the crater for two years past." [1]

Under date of January 30th, 1854, he continues: "Changes have been slowly taking place within the crater. A gradual rising is going on in the whole floor of the crater. This is effected by two causes, — first, by the uplifting forces below, as gases, igneous fusion, etc., — and second, by repeated overflowings. The former is more uniform and general, the latter irregular and partial. You are aware that all the central part of the floor of the crater, embracing nearly one half of its area, is an elevated plateau, the highest points of which are now some six hundred feet above what was the floor after the eruption of 1840. This central elevation rises in some places gradually, in others abruptly, from the surrounding floor. On the east and south-east its mural walls are perpendicular, presenting a dark, lofty, and frowning rampart which no human foot can scale. Of course the black ledge is now a lower plane than this central table, at its highest point, by about two hundred feet. Many parts of the black ledge have also been elevated by subterranean forces. From repeated agitation of the sea around our shores,— instances of which have recently occurred, — we are led to think that submarine eruptions are occasionally taking place on the submerged portions of Hawaii, or from volcanic mountains and cones covered by the waters of the Pacific." [2] **1854.**

July the 18th, 1855, Mr. Coan writes: [3] "For months past this awful furnace has been brightening and glowing, and raging and roaring with fearful intensity. The action, however, is all confined to the great dome and the girdle between the central table and the crater walls; while the elevated interior is unaffected, and even begins to produce plants and ohelo-berries. But it is surrounded by the burning streams of Phlegethon, and stands as a burnt island in a sea of fire. The great dome (over Halemáumau) is thundering and throwing up columns of dashing fusion from its horrid throat to a height of two hundred feet, while its walls tremble at the fury of those waves which rage and dash within. Occasionally a burning river bursts through the rent chasm near its base, and rolls in glaring waves over all that region, flooding the heavens with light, and filling the spectator with mingled emotions of delight, of awe, and of terror. But this is not half. The whole of the surrounding belt, from its periphery at the base of the great walls of Kilauéa, to the elevated central platform, and even eight miles in circumference by half a mile in diameter, is in a state of intense activity. Over this surface I could count sixty lakes of fusion. The whole of this surface is not, of course, broken and fused at once; but it is everywhere rent with fissures, studded with burning cones, and dotted with boiling lakes; and even the solid portions of the surface are so hot as almost to crisp the sole of one's shoes, while the smoke and the pungent gases render it difficult to travel in some parts and impossible in others. **1855.**

"During the last week in May and the first in June, visitors and passing travellers reported a fiery girdle around the whole circumference of Kilauéa, along the base of her lofty walls, — and so intense was the heat, so suffocating the gases, so fearful the hissings, so awful the surgings, and so startling the detonations, that horses wheeled and plunged with panic, and men retired from the old Ka-ù and Hìlo road which, as you may recollect, lay

[1] *Silliman's Journal* [N. S.], vol. xvi., p. 46. [2] *Ibid.* vol. xxi., p. 46. [3] *Ibid.* vol. xxi., p. 100.

near the upper precipice, and passed the great fissure at a respectful distance. And I have been told by those who observed and felt it, that so great was the heat on the road above the western precipice, seven hundred feet above the fires, that they were obliged to hold their hats between their faces and the crater and pass rapidly along to avoid it. The upper banks also of the crater are smoking and steaming intensely.

"For twenty years I have watched the movements of the great crucible of Nature — this Hawaiian volcano — with intense interest, and never, perhaps, have I seen the fires more extensively distributed over the crater, or more active and vivid in their play."

Under date of October 22d, 1855, he continues: "After this the action gradually moderated until the summit crater [eruption of 1855 on Mauna Lòa] broke out, and it remains now much as it was then. There are now about a dozen open lakes of raging lava in Kilauéa, extending in two semicircular lines from the great fountain lake, Halemáumau, along the eastern and western sides of the crater, and evidently forming vents to igneous subterranean canals which are carrying the incandescent floods from this great active vent to the northern parts of the crater, sometimes overflowing this region and sometimes heaving up the ponderous superincumbent strata, like the surface of an agitated ocean. The great dome over Halemáumau is swept away, and a raised and jagged rim from twenty to sixty feet high, now encircles it. The fusion may be one hundred feet below. The movement of the streams northward is distinctly seen through the valves or vents mentioned above. The encircling belt has been raised from one to two hundred feet since last April, first, by uplifting forces; second, by successive overflowings."[1]

1856. Under date of October 22d, 1856, he writes: "During the whole of the past year Lua Pélé has been getting more and more profoundly asleep. A little sluggish lava is found in the great pit of Halemáumau, and the steam issues from a thousand vents. But there is no subsidence of the floor of the crater. This vast area of hardened lavas keeps its elevation some six hundred feet above the level of the floor that was formed at the eruption of 1840."[2]

1857. September 1st, 1857, Mr. Coan writes: "I was at Kilauéa in June last. Pélé was rather quiet. All the area of Halemáumau is now a deep basin encircled by a rim consisting, in some places, of a bold perpendicular precipice, and in others of an inclined plane of unequal angles rent into numerous yawning fissures, and strewed with burnt masses of scoriæ. The bottom of this basin is rent and smoking, and studded with a few cones near the centre and enclosed by a jagged rim from twenty to fifty feet high, is the lake of fire which has burned from time immemorial. It is about one hundred feet below the rim, and some five hundred feet in diameter."[3]

1859. During the eruption of Mauna Lòa, Kilauéa was visited to see if any extraordinary action was visible, but it was comparatively quiet. The fires showed no sympathy with those being poured out ten thousand feet above.

Visitors to Kilauéa were more numerous after the grand eruption of Mauna Lòa of this year, but for several succeeding years they had little to report, but the ordinary activity of the crater. The Halemáumau always exhibited fire, and the cracks poured out steam and vapor, and the accounts of the action varied with the impressibility of the various reporters. Although no marked change took place, the vast abyss was slowly filling up, and its surface became more and more uneven and broken. The very slight shocks of earthquakes, not

[1] *Silliman's Journal* [N. S.], vol. xxi., p. 144. [2] *Ibid.* vol. xxiii., p. 438. [3] *Ibid.* vol. xxv., p. 136.

uncommon on the islands, were not noticed particularly for two or three years on Hawaii, while on Oáhu several were perceived. An eruption was almost desired, as those from Kilauéa usually reach the sea through an uninhabited part of the island. It almost seemed as if the crater was at last strong enough to hold its weighty contents, and would once more empty itself over its rim, and even raise its outer walls.

Fig. 37. The Crater of Kilauéa from the northern bank.

In visiting Kilauéa in 1864, with Mr. Horace Mann, we approached it from the south-west on the Ka-ù path. For ten miles we had seen the cloud of smoke over the crater, and for more than half that distance we had traversed beds of pahoehoe, and large tracts of sand, deep and difficult for our horses. No a-a was visible from the path, and but little scoriæ. The eruption of 1789, is said to have thrown out most of the sand, but the winds have entirely changed its original location. It is dark, fine, and uniform, and it now lies covering the solid pahoehoe in places to the depth of several yards. Soon after one o'clock we came upon the brink of the crater. From below us steam and sulphurous vapors rose in a sluggish column, but we saw no fire and heard no noises. The great sunken plain before us, covering six or eight square miles, looked bright in the clear sunlight, and even the walls on which we stood were of a light gray color. The whole circuit of the walls on the northern and western sides is much cracked and interrupted. We rode along over several cracks, one of which, a little more than a yard wide, had opened about a year since, accompanied by an explosion heard distinctly at a distance of twenty miles. Some of the cracks were parallel with the edge of the abyss, others were at right angles to these, and in one place the small cracks were so numerous as to resemble a geometric spider's web. 1864.

Passing over the high cliffs on the north-west, which are the highest part of the circuit. the road leads down by a steep descent of fifty feet to a plain a mile long and three quarters of a mile wide, gravelly and covered thinly with dwarf ohia and ohelos, and thickly dotted with small oval or circular fumaroles, from which steam was issuing, not as at the Geysirs in California with great noise, but as a quiet, respectable tea-kettle pours out its vaporous offering. The steam had no odor, and ferns and other plants grew luxuriantly over the openings. On the leeward side of these steam-holes the muddy and tenacious red soil retained pools of excellent water condensed from the steam. There was no trace of sulphur or acid in it that could be detected by test papers or the taste. The rock through which these cracks passed was completely decomposed from a hard gray clink stone to a red loamy earth, soft and worn smooth by the ascending vapor. It was quite evident that these fumaroles were not originally formed by the vapor, but were simply cracks, through which the steam escaped, and the circular shape resulted from the falling in of the surface gravel and soil. The steam was quite hot, and we saw the remains of several cattle who had gone too near in search of water.

On the northern edge of this plain are extensive sulphur banks, that is to say, they cover a large space although containing but little sulphur, under a perpendicular ledge of clink stone nearly a hundred feet high. They are simply great piles of the decomposed lava, through which steam and sulphurous vapors constantly escape through a thousand apertures, depositing beneath the crust the most beautiful, almost acicular crystals of sulphur The soil formed by the decomposition of the rock by sulphurous vapors is quite unlike that resulting from the action of steam alone; it is light gray or yellow, and does not form a plastic mud as easily as the latter, which is red and smooth to the touch. In some places the sulphates of oxides of copper, iron, sulphates of soda, lime, and alumina were forming within minute fissures, and the silica thus set free was gradually consolidating the earth into a firm crust whenever the action of the steam ceased, and we could often raise large slabs of this curious conglomerate. Metamorphism was progressing rapidly under the combined influence of heat and moisture. Twigs and leaves were fast passing into the condition of fossils in this hardening earth. All the sulphur found here is deposited from the vapor, and seems to be tolerably pure and is of a light-yellow color, indicating the absence of selenium. There would seem at first to be no doubt that this plain has sunk to its present position, as it is surrounded, except towards the crater, by a wall of the same material; but this is not the case. Where the lava-beds of this portion adjoin the other walls of the crater, there is no fault, the strata are continuous, and this plain was once the bed of Kilauéa, — a black ledge.

As soon as our men came up with the blankets, we engaged guides and went down into the crater. The descent was steep and winding, and we passed over several terraces, which were the result of a sinking or falling in, as their strata were inclined and much broken, and came under the grand pali of compact lava figured in the "Narrative of the United States Exploring Expedition."[1] A descent of more than four hundred feet brought us to the bottom, and we stepped from a gravelly shelving bank on to a black lava which had broken out last year under the north bank, and overflowed this end of the crater. Where it touched the gravel bank it had glued to its under surface the small fragments of stone, but had not altered their appearance, and all along the edge it was cracked, and laid up on the bank as

[1] *Narrative of United States Exploring Expedition*, vol. iv., p. 1[illegible].

if, on cooling, the lava had fallen about a foot. The surface was covered with a thin scaly vitreous crust, which crumbled beneath the tread, sounding like snow on a cold morning, and thus a very distinct path was made to the Halemáumau, the enduring house of the goddess Pélé. The lava beneath this crust, however, was so hard as to give out abundant sparks as the steel-nails in my shoes scraped upon it. When hard it was often iridescent, like some anthracite coal, and so closely resembling this mineral that the difference would hardly be detected on a cursory examination. The fresh lava exactly resembled that from Mauna Lòa in the flow of 1859. Three quarters of a mile over this uneven lava, and we came to a long wall of lava composed of fragments of all sizes and shapes, very solid and heavy and full of small grains of olivine; and this wall, which is concentric with the main wall of Kilauéa, is said to rise and fall and sometimes disappear, which seems to be a fact. although no one has ever seen it in motion. It is the fragments broken from the edge of the crater by an eruption and floated out to its present position. An unpractised eye would see no marks of fire on the rough granite-like masses. Caves, cracks, and ridges make the surface very uneven, and after walking two miles we came to several large cracks

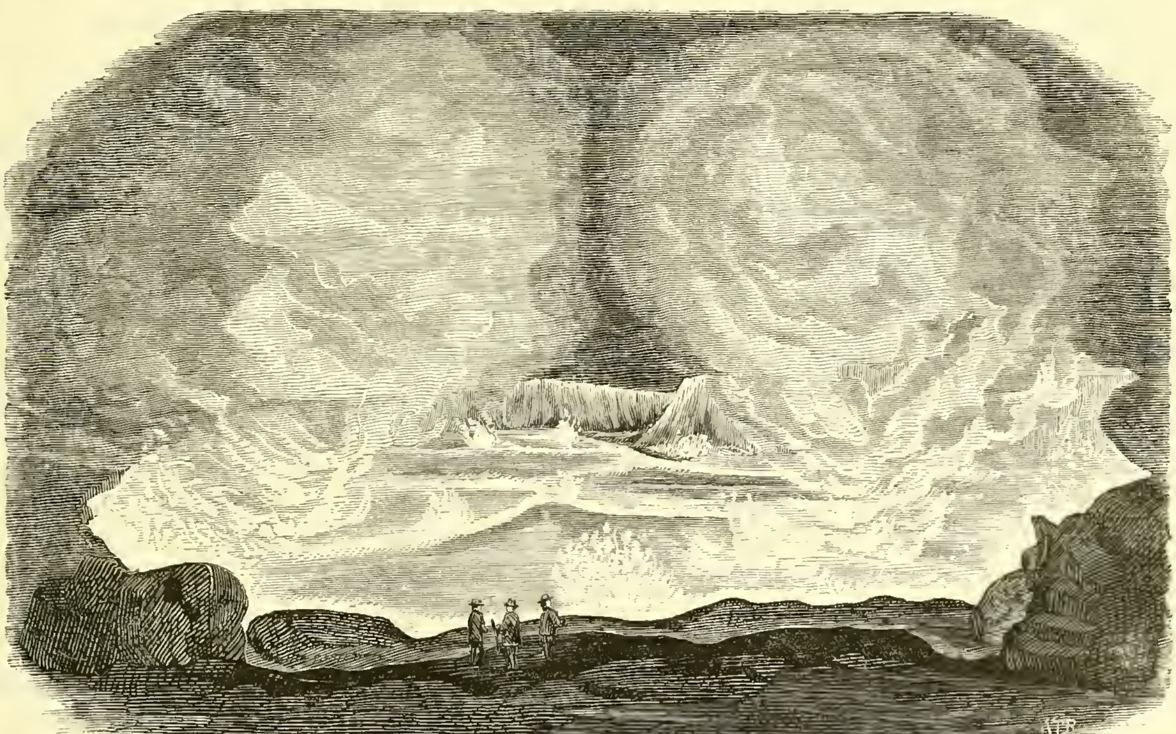


Fig. 38. Halemáumau.

of great depth, but not more than a yard wide, and then a wall enclosing an amphitheatre down which we climbed on the loose slabs of lava.

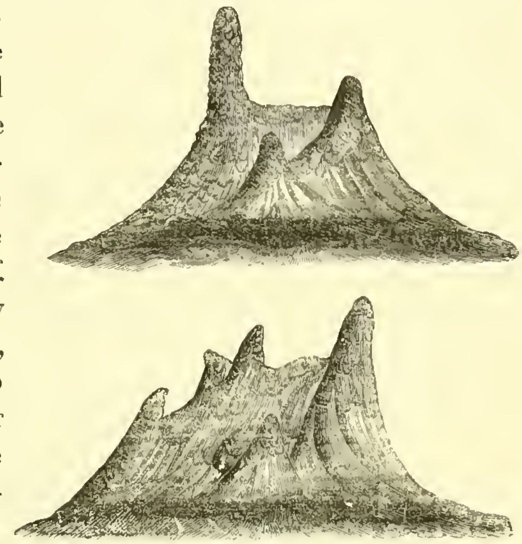
The whole bottom of the crater is above what Prof. Dana describes as the Black Ledge, and although no fire is visible over the northern and eastern portion, steam constantly rises from many cracks, and the caves are often uncomfortably warm. When we were near the Halemáumau, we came to a cone formed of spattered lava and cemented scoriæ, some twenty-five feet high, with a bright light at its apex. This was the first fire we had seen, but we passed by, eager to reach the great lake. This we reached after ascending a gradual incline. It was about eight hundred feet in diameter, and the lava was fifty feet below the cliff on which we stood, covered with a dark crust which was broken around the edges, and there the blood-red lava was visible, surging against its walls with a dull, sullen sound. The smoke was blown away by the wind so that we were able to stand on the very verge of the pit; but the heat was so great that we were obliged to hold our hands before our faces.

The walls on which we stood, and where we intended to sleep, were thickly covered on the side towards the pit, with waving wooly Pélé's hair, which we saw forming continually. The drops of lava thrown up drew after them the glass thread, or sometimes two drops spin out a thread a yard long between them, and the "hair" thus formed either clings to the rough sides or is blown over the edge where it catches on any projecting point. The drops are always black, or a very dark green on the surface, but light green within, porous and excessively brittle, and the thread is transparent, and when first formed, of a yellow or greenish color. Occasionally a crack would open across the lake, and violent ebullition commence at various points along its surface. There were two small islands in the lake which the lava seemed seeking to destroy. The current would often set in toward the banks, and it appeared as if the whole lake was about to be drawn in, as cake after cake broke off from the surface and disappeared. But it would soon cease, and then run towards another point of the wall, and I could not see that it was oftener on one side than another. As a cake of lava parted from the crust the red lava rose above the crack, running on the surface, and as the crack grew wider, cooling rapidly, and being drawn out much like molasses candy. While white hot, the lava was as liquid as water, but it rapidly assumed the viscid condition, and then the solid. I threw a stick of dry wood on the surface the instant it became fixed after a violent bubbling, and it was ten minutes before any smoke was made, and it was only when a crack opened under it that it was consumed. The motion was always from the centre, except when the lava was thrown back in spray from the caverns which extended under much of the wall.

We laid down in our blankets on the eastern edge where the walls were highest, and the wind drove away the smoke, and soon fell asleep. About nine o'clock I got up and moved to the very edge of the pit to view the molten mass to better advantage, and warm myself, as the wind was quite cold. The moon was up and almost full, but her orb was pale beside the fires of Pélé. Finding the place quite comfortable, I lay down and went to sleep. At twelve I awoke with a start, and found myself in the midst of a shower of fiery drops, some of which were burning my blankets. I shook myself and jumped back, looking at my watch to note the time, for I thought a great eruption at hand, and then stood gazing at the strange scene for some time before I thought of calling my companions. The whole surface of the lake had risen several feet and was boiling violently and dashing against the sides, throwing the red-hot spray high over the banks, causing the providential rain of fire which awoke me to see this grand display. There was no noise except the dash and the sullen roar. When I could think of anything else, I called the others, who were asleep several rods from the edge, but only succeeded in awakening the guides, and just then a drop came plump on to a greasy paper we had brought our supper in, and it blazed up so suddenly that one of the kanakas thought a new jet was opening at our feet, and ran off to some distance. Failing to arouse my companions by calling, I threw a handful of small stones at them but without effect, and I had to climb down and shake them roughly. When they had got to the edge the action had greatly diminished, and in a few minutes more the dark crust again covered the central portion, and we all went to sleep.

I was glad to see such distinct flames, as it has been denied that they exist in Kilauéa. They burst from the surface and were in tongues or wide sheets a foot long and of a bluish-green color, quite distinct from the lava even when white-hot; they played over the whole surface at intervals, and I thought they were more frequent after one of the periodical risings of the surface in the pit.

In the morning we found it very misty, and the mist soon turned to rain, but we went to the cone we had seen the evening before, and climbing its sides looked into its red-hot mouth. It was nearly full of melted lava, but although we tossed in scoriæ we could not excite it. Another cone with several pinnacles called the "Cathedral" we did not visit, as no fire was visible, although smoke poured from it copiously. The rain caused steam to rise from the cracks over the whole surface of the crater, and we got quite wet, and our views were wholly cut off. At half-past seven we were in the saddle on the way to Hìlo, which was only twenty-nine miles distant, but the road was so rocky in some places and so muddy in others that we were obliged to walk our horses all the way, and it was twelve hours before we dismounted at the house of the excellent missionary who has done more than all others to record the volcanic phenomena which have taken place on Hawaii during the last thirty years. Kilauéa lies in Mr. Coan's district, and he passes its brink at least twice a year.



Figs. 39–40. The Cathedral in Kilauéa (——→ West and North-east.)

On the second of August, 1865, I again visited Kilauéa, this time with Mr. C. W. Brooks of San Francisco,[1] to make arrangements for a survey. The appearance was 1865. much the same as last year, although the bottom had evidently risen, and several new cracks formed, while others had closed. The banks of the Halemáumau had changed considerably. The platform on which I slept before was gone, and the diameter was now at least a thousand feet. The islands had disappeared, and the lava was not more than thirty feet below the top of the bank. We went down in the crater in the evening, and fell asleep with the usual resolve to wake up now and then to enjoy the fire-works; but we were so weary with our tiresome ride from Hìlo, that we slept until after midnight, when a puff of sulphurous vapor from a crack under our heads, waked us up choking, and we beat a hasty retreat. In a few minutes, however, the gas ceased to blow, and after enjoying the changing fire of the lake for half an hour, we slept until five in the morning, when our guide advised us to return, as we were to breakfast on the upper bank some three miles distant. We went round by a new lake, which had opened during the winter on the northern side, near the bank. It was small, hardly two hundred feet long and fifty wide, but the melted lava was not more

[1] I was particularly glad to secure the company of Mr. Brooks, as he had visited the volcanic regions of Italy, and other parts of the world, and was well acquainted with their phenomena.

than a foot below the surface, so that we could work it with our sticks. It was blood-colored and very viscid, and exhibited the same motions as the larger lake, — the currents to the sides, and the cracking and bubbling, but on a much smaller scale. Fire was visible at night at various points between this and the Halemáumau. Near this lake my kanaka picked and brought me a poor *Rumex* which was growing in a steam crack on the hard black lava which had run over from this lake last winter.

The next night I slept on the upper bank, while several of our party spent the night in the crater. They could not approach the place where we had slept the night before, owing to the change of wind, and during the night the whole shelf fell in with a loud noise. This formed a small island which was soon broken and melted by the boiling lava.

August 22d, I returned to Kilauéa from Hìlo, having since my last visit explored the district of Púna, and the pit craters on the flow of 1840. I brought with me surveying instruments and a photographic apparatus, and after spending a day in selecting stations and drilling my kanakas in chaining, commenced the survey from the house on the northern bank. Going eastward the ground was covered with bushes and full of steam cracks which made chaining very difficult. Waldron's Ledge, so called after the purser of the United States Exploring Expedition, is a continuation of the wall which bounds the plain near the northern sulphur banks, and on meeting the crater's edge it turns to the east towards a large lateral crater called *Poli-o-Keàwe*,[1] enclosing this with a circular wall four thousand feet in diameter,

Fig. 41. Poli-o-Keàwe from the Western bank of Kilauéa.

and deeper than the main crater at present. Descending the steep precipice we came upon the gravelly isthmus which connects the two craters. In the midst of this a lava stream issued in 1832, and ran down into both. Its appearance is still fresh, and where it descended into Kilauéa over a precipice of 60° and more than two hundred feet high, it has formed a fine lava-fall perfectly continuous, although for a short distance it is nearly perpendicular. It is hollow, and of small volume.

The ascent from this isthmus is not so steep on the southern side, and above, the soil is gravelly and barren, supporting but few plants. The wall of Kilauéa is much cracked and broken on this side and is also much lower. The second lateral crater, *Kilauéa iki*, on the

[1] This is the crater called Little Kilauéa on Wilkes' chart.

south-east is much smaller than Poli-o-Keàwe. Its walls are quite perpendicular on the side towards Kilauéa, and the depth is greater than that of the main crater. The bottom is gravelly, level, and a small mound rises near the northern side. Near the edge of Kilauéa was a ledge of sandstone much split into parallel vertical plates, and evidently formed by the cementation of the volcanic sand common on the banks on this side. There were many curious circular depressions in the hard gravelly soil, about three feet in diameter and from six to eight inches deep, which I did not at first understand. I soon found that they were over cracks in the subjacent rock, and the sand, which is quite loose a foot below the surface, had settled into these small fissures, causing the depression in the sandstone above, which is almost as flexible as Itacolumite. There were evidences of severe showers over this plain, as the torrent channels were numerous and deep, and always emptied into the crater.

At the edge of Kilauéa iki, as it was late in the afternoon, my kanakas built a stone house to shelter the instruments, and we decided to cross Kilauéa as the easiest way home. We climbed down a steep gravel bank formed by the action of sulphurous vapors on the rock of the walls, crossed a small sulphur bed from which steam was issuing, and continued our way over the portion of Kilauéa which was overflowed the year before. It was very disagreeable walking, as the crust was quite thin and brittle, and we constantly cracked through, only a foot perhaps, but there was a constant feeling of insecurity, for we could not know but that the breaking crust covered a deep crack in the harder lava beneath. Half way across we found a cone three or four feet high covered with spatters of lava of various colors. Crossing the crater again the next morning in the rain we found it difficult to find our way owing to the steam, but finally reached the bank. It was two o'clock before the mist cleared away enough to permit the use of the theodolite. The large sulphur bank near this side of Kilauéa was of a bright green color owing to a large proportion of sulphate of protoxide of iron which seemed to be constantly forming. The sulphur is much of it in large amorphous masses, as if melted.

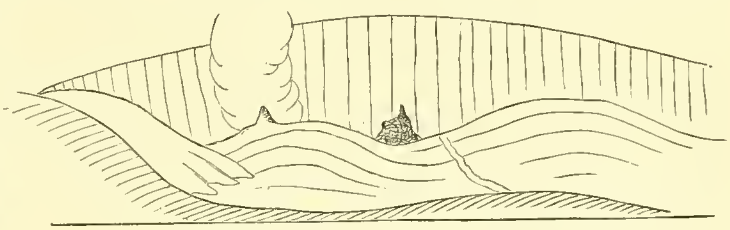


Fig. 42. Outline of the south end of Kilauéa.

The ground on this side of the crater is smooth, free from stones, and so terraced and sloped that it is difficult to define the boundaries of Kilauéa. As no rock is visible it is impossible to determine the direction of the disturbing forces, but the present condition of the bank seems to indicate a falling in of the wall in several places, probably over one or more of the subterranean streams that have deluged Púna. The soil of the mountain is thinner here than elsewhere, and most of the subterranean eruptions have forced their way through it, forming a line of craters to the sea. One of Wilkes' signal posts was found rotted off at the base, but otherwise sound.

On the south-west side the smoke from the Halemáumau was very suffocating, and I was obliged to pass through it with a wetted handkerchief to my face which was quickly dried by the smoke, which was wonderfully free from aqueous vapor. The ground was covered with Pélé's hair which collected on the leeward side of the ridges and stones, and also extensive beds of the Hawaiian pumice or "limu." This limu is identical with that seen on

Mauna Lòa, and is the froth of the burning lake. As the chain was drawn through it, the steel became completely polished. It was so loose that in one place I sank up to my waist in it. Stones and fragments of scoria were lying about apparently loose, but we found it almost impossible to break them off, so firmly were they cemented to the gravel rock below. The action of the sulphurous atmosphere soon dissolves the Pélé's hair, and this with the silica in the gravel itself makes a solid cement. There is an easy descent into the crater at the south-west end, and beyond this the nearly perpendicular rock wall again begins.

I reached the highest point on the Ka-ù road about dark, and sent home the instruments, while I followed slowly along the bank, watching the fires which were gleaming brightly seven hundred feet below. The new lake close beneath the bank was exceedingly beautiful, as it emitted but little smoke, and constantly cracked and broke up its crust, forming an everchanging network of fire. A line of fires was burning all the way between the two lakes, but the level of the new one is more than fifty feet below the old.

Saturday it was rainy and impossible to obtain sights with the instruments, so I went into Kilauéa to explore the caves. The Halemáumau was not in a very lively condition, and passing beyond that, I went into a cave of considerable extent, where the curious siliceous tubes had formed on the rock roof, and obtained many of these fragile specimens some of which were coated with beautiful white crystals. This cave was more than fifty feet below the level of the melted lava in the lake, and the walls did not seem very secure. A lava stream had recently poured into the mouth of the cave, but there were no vapors, nor any uncomfortable heat. Taking advantage of a change of wind, I passed around the lake, and ascended a cone with two peaks formed by lava spatters, but completely closed on the top, as nearly all the others in the crater were, and found steam hissing from many apertures. On breaking off the crust beautiful crystals of various salts were found thickly coating the under surface, and in one place we found much nitrate of potassa. I went from cave to cave, from cone to cone, collecting various kinds of lava and several salts, and finished by a bath in a steam cave, where the steam issued from the floor at an agreeable temperature, and condensed on the roof, falling in rain. The water was quite sweet, and no smell of sulphur was noticeable in the cave. On the roof the little tube stalactites were constantly forming by the solution of the silica in the rock above, and I broke off the brittle, twisted tubes sometimes a foot long. On the floor the drops have made stalagmites of various forms.[1] This steam bath was most delightful after the smoking I had just experienced in a cave where the end was red-hot, and into which my natives did not dare to go.

Sunday was the first bright day I had had, and the pulu[2] pickers from the neighboring region came to my hut after the morning service, and told me the names of the various parts of the crater, and legends of ancient eruptions. Monday was again rainy, but I completed my measurements, and in the evening made a series of observations to determine the declination of the magnetic needle. The electric currents in the lava and the large quantity of iron in the rock, made strange work with the compass; I have seen the needle suddenly turn through an arc of forty degrees. The variation of declination will be

[1] I shall refer more particularly to these stalactite caves, when describing the minerals.

[2] Pulu is the silky covering of the opening fronds of several species of tree ferns, and is exported in large quantities to California for beds, &c.

seen in the table on another page. The remainder of the week was too cloudy to take photographs, and I was reluctantly obliged to send back my instruments, and return to Hìlo.

In May, 1866, Kilauéa commenced a series of discharges all over the surface of the crater which were still in operation in August. New lakes of fire opened along a curve north-west to north of the great lake of Lua Pélé, flooding all that portion of the crater with fresh lava, and reaching even to the sulphur-banks on the southern side of the plain, in a stream about four miles long and from an eighth to half of a mile wide, cutting off for much of this time the usual entrance to the crater. This whole portion of Kilauéa now flooded was about fifty feet below the central area; it is now at least a hundred feet higher than it was last year, but the central plateau has also risen, and the relative height is about the same. The whole appearance of the crater has however changed. The ledge of compact broken lava, which swept around the eastern end of the crater, marking the limits of Dana's Black Ledge, is nearly covered with the successive overflowings, and the caves which formed so interesting a feature of this portion of the crater are filled and obliterated. 1866.

The throes and detonations caused large blocks to fall from the outer walls, and the heaving of the intensely active flood at their base soon removed the débris, thus showing the method in which pit craters may be enlarged horizontally. Travellers who visited Kilauéa while this eruption lasted, speak of the hissings and spoutings, the subterranean rumblings and detonations, as terrific. In August the force of the eruption seemed to be spent, but no subterranean outflow was perceived, and the crater remains full of broken and hard lava. A few more such eruptions will raise the bottom to a level with the upper walls, and Kilauéa will cease to exist as a Pit Crater.

Craters south-east of Kilauéa.[1] The cone craters near Kapóho on the coast of Púna have been described. The same line of volcanic action extends to Kilauéa, and seems to mark the position of an extensive rent in the side of the mountain. No foreigner has well explored this region of craters, as the jungle is almost impenetrable; and the Rev. T. Coan was the first who discovered the craters near the eruption of 1840. Dr. Charles Pickering extended his explorations to a greater distance, and mapped out some of the craters which were afterwards verified by Captain Wilkes. More than fifty cones and pit craters, some of the latter of remarkable size, have been seen, and the number will probably exceed a hundred when the whole district shall be well explored.

The passage through this way has been exceedingly difficult, until the last few years, when the business of picking and exporting pulu has become so important, that paths have been cut by the pulu-pickers, and several stations established for their convenience. The great similarity of the cones and craters in this region, and the fact that they are all formed in the same lava-beds, renders a particular description unnecessary, and I will content myself with a brief account of a journey through the part of the forest where the largest are placed.

Here and there on the way from the coast at Panaù we passed lava streams. Ohia-trees were growing on these, thin and tall, suggestive of Alpine regions; indeed, I have seen precisely such forests on the Swiss mountains, and there was a peculiar grace, which, while pleasing the eye, yet conveyed the idea of a struggle for existence amid the storms which

[1] There is a fine chart of the Púna craters among the maps of the Exploring Expedition.

sweep the rocky slopes of Mauna Lòa. At the height of eighteen hundred feet we entered the fern forest. The fruit of the *Physalis* and *Vaccinium* was abundant, and sandal-wood was occasionally met with at an elevation of two thousand feet. As we came to the fern region, we turned into a path cut through the jungle, and, as the soil was a soft black mould, it had been paved with the stems of tree ferns, which are about six inches in diameter. This "corduroy road" was constructed with great labor by the natives, and we calculated that forty thousand pieces of fern were used to build it. The ferns are cut in lengths of six feet, and many of them sprout and make a green edging to the roadway. This path led through the most tropical region I had seen on Hawaii. Tree ferns whose stems were fifteen feet high to the base of the fronds, and eight to twelve inches in diameter, were mingled with *Myrsine*, *Byronia*, *Pelea*, *Ilex*, and *Metrosideros*, while over all, the long leaves of the *Ié* (*Freycinetia arborea*), the dark glossy green *mailé* (*Alyxia olivaeformis*), and mosses in great abundance covered the stems and branches, and hung in long graceful festoons.

Nearly two miles through this, and we came to a tract of pahoehoe, and here was the pulu station to which the roads had been cut. This is the present residence of a remarkable native who has leased this whole district for the pulu business, — Kaina, the district judge. His house was directly on the line of craters, and only a few rods from steam cracks where his men cooked their food. It was well built, and surrounded with a substantial stone wall. The interior was furnished with bedsteads, rocking-chairs, and other conveniences; and our supper-table was supplied with fresh wheaten bread, milk, butter, eggs, and delicious berries.

West of the house was a large open field where the silky golden fibre of the pulu is dried before packing, and beyond, in the woods, I found curious tubes of lava on an ancient flow, one of which was seven feet high, eighteen inches external diameter, and with a bore of eight inches. It was brittle, and on breaking it off, I found the hole was six feet deep, making its whole length thirteen feet. Others of the same height were near by, and their sides were always thicker towards the source of the flow. Externally they are rough, and look spattered, but the top was smooth, and sometimes projected like an umbrella. Where several were in close proximity, a slab of lava was supported like a roof on columns. The lining of the tube was smooth, and much more compact and vitreous than the exterior. The trees which served as cores have entirely decayed, and were mostly tree ferns, although I think that I detected some ohias. I followed the stream down some distance to ascertain the cause of its subsidence, which must have been rapid, and found that a fissure had opened and swallowed most of the lava. Judging from the great size of the trees over its surface the flow must be quite ancient.

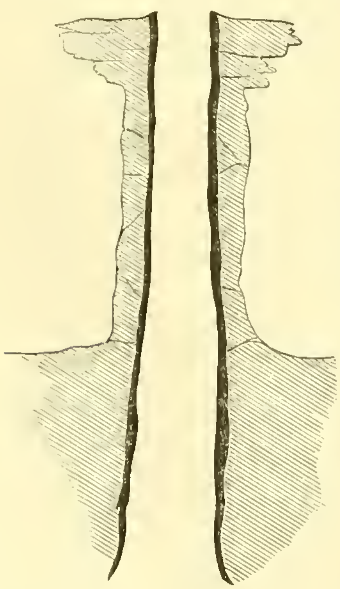


Fig. 43. Tree-casts in a lava stream.

Tuesday I went with my boy Ioane to explore the woods. As I followed a path made by the pulu-pickers through the dense forest, I came upon a large hole on the edge of the path which proved to be the entrance to a cave of great depth. The path had been turned to one side to avoid it, and in the dark it would be exceedingly dangerous. Such holes are common in this part of Púna, and natives occasionally disappear mysteriously. Brushing through the bushes I came to a precipice forming the edge of a crater nearly three quarters of a mile in diameter and seven hundred feet deep. The sides were quite perpendicular, and in

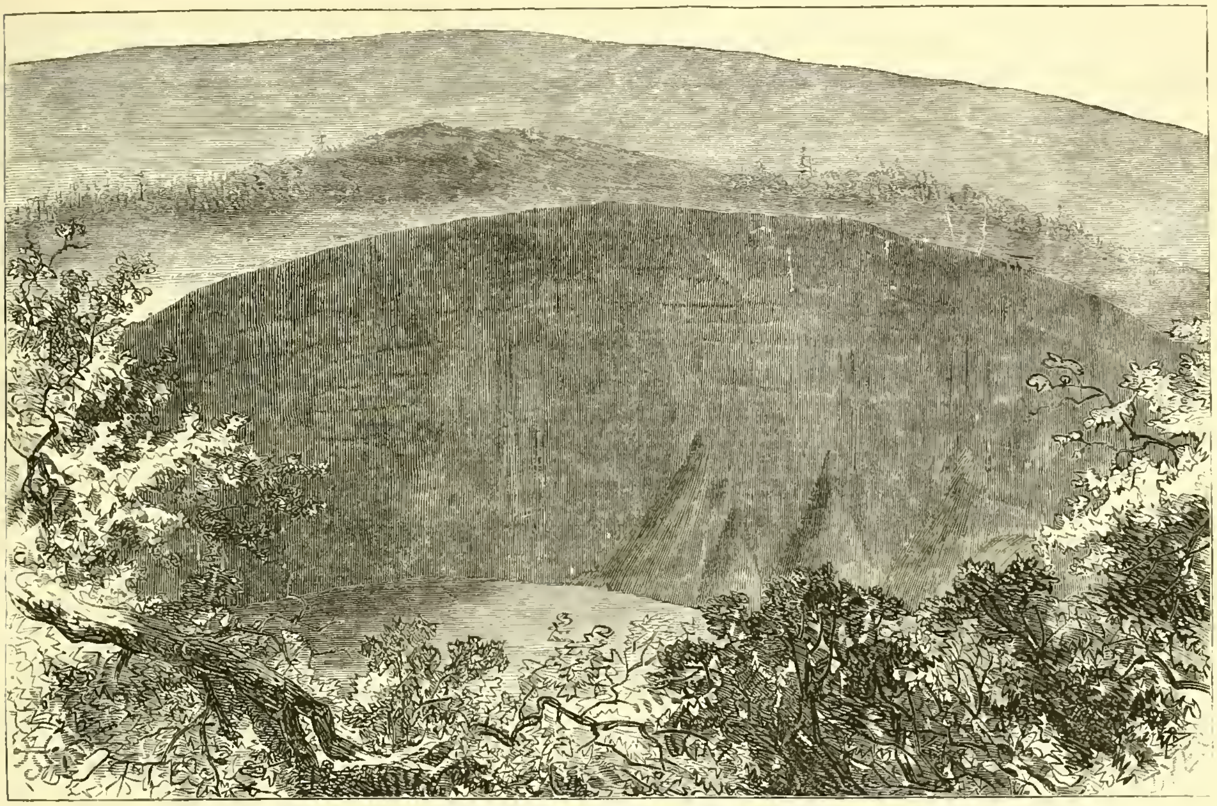


Fig. 44. Pit Crater in Púna.

most places impassable. The bottom was level and gravelly, with a thin growth of ohia, and at the western end, directly under the wall, was a much deeper pit, indeed the deepest I have seen on Hawaii. Beyond this was a cone of some size, near which the eruption of 1840 reached the surface first, passing under the cone ; (see Fig. 44). Half a mile beyond this is another pit crater, smaller, and covered on the bottom with black lava. Following the line down in a south-easterly direction, I came to the steam cracks, which extend for several hundred feet, and since tradition existed have furnished the natives of the neighborhood with the means of cooking. The pahoehoe has been decomposed into a soft red muddy soil, covered with a hard crust, which may be raised in slabs. Under these are most beautiful crystals of sulphur in clusters, but of too fragile a nature to be removed.

Beyond these cracks was a much larger crater, being elliptical, with a major axis a mile long, and about five hundred feet deep. The perpendicular walls were prismatic in various places, and at the west end were rent asunder, affording an easy descent to the bottom, which was gravelly, level, and free from cracks or holes. The walls of all the craters were compact gray clinkstone in deep strata, like the walls of Kilauéa, and no recent lava was visible. Several dykes were seen at right angles to a line from Kilauéa to Kapóho.

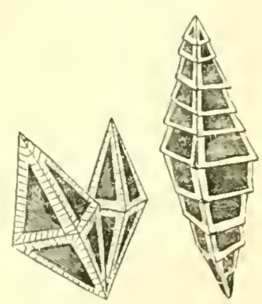


Fig. 45. Sulphur crystals.

Periodicity of Eruptions on Hawaii.

Our knowledge of the Hawaiian volcanoes covers too short a period of their history to determine with any certainty the laws which regulate the discharges. The following table contains all the eruptions that have occurred since the discovery of the Islands: —

Kilauéa.	Mauna Lòa.	Mauna Hualalaì.
1789.		
1798? No record.		
		1801.
1806? No record.		
1814? No record.		
1823.		
1832.	1832.	
1840.		
	1843.	
1849? Subterranean.		
	[1851. 1852.]	
	1855.	
1858? Subterranean.		
	1859.	
1866.	1866.	

It will be seen that while Kilauéa fills up and breaks out in about eight years, Mauna Lòa has poured out lava streams at intervals of eleven, eight, three, four, and seven years. The action of Kilauéa indicates a constant and regular supply of lava, which accumulates to about the same height and then flows off. In Mauna Lòa the action is nearly as regular, if we consider the different elevations from which the discharge takes place. At Kilauéa it is always about three thousand feet above the sea, as the reservoir of lava subsides to this level, but on Mauna Lòa the discharges have been at thirteen thousand feet or a little below the bottom of the summit crater, nine years after at the same elevation, which afterwards changed to ten thousand feet, thus draining the mountain three thousand feet lower than the last, and requiring three years to fill up to twelve thousand feet, the height of the next outbreak, which continued to flow eighteen months; four years after at the height of eleven thousand five hundred feet, and finally after seven years of repose, at the height of twelve thousand five hundred feet.

Usually the eruptions from the several vents have been quite independent, and only twice, in 1832 and 1866, have they been simultaneous. The intervals of neither mountain seem to be increasing, and we learn from native tradition that since the island was peopled by the Hawaiians, some two thousand years since, eruptions have taken place with about the present frequency at Kilauéa.

Volume of Lava ejected.

1823	Kilauéa		27.000,000,000	cubic feet.
1840	"	Exploring Expedition	15,400,000,000	" "
1843	Mauna Lòa	These are estimated roughly, as the flows have never been surveyed or measured.	17,000,000,000	" "
1852	" "		18,000,000,000	" "
1855	" "		38,096,000,000	" "
1859	" "		28,560,000,000	" "

The other eruptions were either subterraneous, or no sufficient data exist for an estimate. The volume of a discharge of Kilauéa is probably pretty constant.

Review of the Hawaiian Eruptions.

The eruptions that have been recorded on the Hawaiian Islands are then as follows: —

I. In 1789 an eruption from Kilauéa, not seen by any foreigner. It was accompanied by ejections of black sand and great volumes of hot sulphureous gases, both from the crater itself, and from fissures on a south-east line between Kilauéa and the sea. The earthquakes were violent in the neighborhood, and nearly a hundred men lost their lives by the hot and poisonous gases.

II. In 1801 Mauna Hualalaì poured forth from near the summit a torrent of lava which filled up a deep bay, and changed the whole aspect of the coast.

III. In 1823 Kilauéa emptied itself by a subterranean outlet which reached the surface some miles south of the crater, and poured a torrent of lava through the district of Ka-ù. The stream is nearly five miles wide where it entered the sea near Kápapala.

IV. In 1832 both Kilauéa and Mokuawéowéo were active. In Kilauéa the lava broke out on the narrow neck of rock between the main crater and Poli-o-Keâwe, in the spot where Lord Byron had encamped some years before, and flowed down into both craters. The amount of lava ejected here was small. The lavas were previously fifty feet above the Black Ledge of Ellis, and between June and September had fallen some hundred feet. It is not known where the lava reached the sea. June 20th, Mauna Lòa was pouring forth lava from the summit in every direction, and continued in action for two or three weeks. The light was visible at Lahaìna.

V. In 1840 Kilauéa emptied itself in a south-east direction through the district of Púna. The stream of lava reached the sea at Nanawálie, a distance of forty miles, in four days. Owing to the exceeding roughness of the country the depth varied from twelve to two hundred feet, and the width from five hundred feet to three miles. For two weeks the light was so brilliant, that at Hìlo and places forty miles distant, the finest print could be easily read at midnight.

VI. In 1843 Mauna Lòa broke out near the summit. Two large craters were formed, and two streams of lava poured out from fissures, one flowing westward, towards Kóna, and the other and larger one towards Mauna Kéa on the north a distance of nearly thirty miles, when it divided, one branch turning towards Waiméa, and the other towards Hìlo. This eruption continued nearly four weeks.

VII. In 1852 an eruption broke forth on the north side of Mauna Lòa, shooting up great jets from two to five hundred feet high.

VIII. In 1855 an eruption took place from the same vicinity. It continued for about thirteen months, pouring a stream of lava down the mountain slopes for sixty miles and covering nearly three hundred square miles.

IX. In 1859 another eruption took place from Mauna Lòa, throwing up fountains of lava as in 1852, and, after flowing some forty miles, poured into the sea at Wainanalíi.

X. In 1866 both Kilauéa and Mauna Lòa were active, the latter pouring out several small streams of lava.

Theoretical Formation of the Hawaiian Group.

In describing the various islands of the group, slight allusion has been made to the theory of their formation, because it was necessary to compare each with all, and especially to examine the active formative processes now going on in some portions of Hawaii. The external appearance of all the islands and their physical history in recent times, so far as known, have been carefully though rapidly reviewed, and it now remains to trace back the history of this group as completely as may be from the record referred to.

Formative and destructive agencies have worked in succession, and together, to bring the islands to their present condition, and are both still at work on Hawaii. On the other islands the volcanic forces which raised their mountains have ceased to act, and only the destroying forces of the atmosphere alter the external features of the land. It is with the formative processes we have to deal principally, and we may first consider the phases of volcanic action here exhibited.

The linear direction of volcanic action has long been a recognized fact in geology, and the Hawaiian Islands are fine examples of the result of such action, but it is difficult to determine the extent of the original fissures from which their lines of volcanoes were ejected. According to one theory there are two fissures extending from north-west to south-east, one commencing with Waíaleale, and including Konahuanùi, Olokùi, Háleakala, Kohála, and Kéa; the other closely adjacent, reaching from Kaàla to Kilauéa, including the remaining peaks. The other and more probable theory supposes a west-north-west main fissure, with lateral subordinate fissures.

Prof. Dana considers "that there were as many separate rents in the origin of the Hawaiian Islands as there are islands. That each rent was widest at its south-east portion. That the south-easternmost rent was the largest, the fires continuing there longest to burn. That the correct order of extinction of the great volcanoes is therefore nearly as follows: —

"1. Kauaì.
"2. Western Oáhu, Mauna Kaàla.
"3. Western Máui, Mauna Eéka.
"4. Eastern Oáhu, Mauna Konahuanùi.
"5. North-eastern Hawaii, Mauna Kéa.
"6. South-eastern Máui, Mauna Háleakala.
"7. South-eastern Hawaii, Mauna Lòa." [1]

A more extended exploration than Prof. Dana had the opportunity of making, completely confirms this view, enlarging the series as follows: —

1. Western Kauaì, Napàli, (Púuokapélé region).
2. Western Oáhu, Mauna Kaàla.
3. Eastern Kauaì, Waíaleale.
4. Western Molokaì.
5. Western Máui, Mauna Eéka.
6. North-western Hawaii, Mauna Kohála.
7. Eastern Oáhu, Mauna Konahuanùi.
8. Eastern Molokaì, Mauna Olokùi.

[1] *Geol. United States Exploring Expedition*, p. 282.

9. North-eastern Hawaii, Mauna Kéa.
10. Lanai, Kahooláwe.
11. Eastern Máui, Mauna Háleakala.
12. Western Hawaii, Mauna Hualalaì.
13. Eastern Hawaii, Mauna Lòa, which with Kilauéa is still burning.

These have been arranged in both lists in accordance with the extent of degradation exhibited, and they comprise the whole series of volcanic vents which have formed the group. Niihau, I believe to have been a portion of Napàli on Kauaì, and Kahooláwe and Molokìni are but subordinate coast craters, or possibly the former is a portion of Lanai.

Kauaì. — In describing Kauaì, I mentioned the remarkable similarity in structure and appearance, between the western precipice of Napàli and the eastern cliffs of Niihau. The strata, so far as examined, correspond, and I cannot but consider the two islands parts of the same.[1] Some vast disruptive force has torn it from its original position and moved it twenty miles without any considerable disturbance of its strata. I own that the force seems improbably great, but we know that Háleakala, a mountain of much greater bulk, was rent asunder, and a segment moved more than two miles, and even greater breaks are supposed to have occurred on Oáhu.

The history of the Kauaì group I suppose to have been this: The original vents from two centres of action poured forth their lava until two mountains were formed in close proximity; the double axis of Oáhu, Molokaì, and Máui, was here also, but instead of ceasing to eject lava when the mountains were completed, there succeeded a period of intense activity, — possibly prior to the formation of a new vent on some of the other islands, — the mountains were broken up forming the ridges of Maunas Kalaléa, Nóunou, Kápu, and the Kolòa Ridge, — a gigantic Somma, — while the lavas again piled up two mountains on the ruins, the eastern one being the larger, as on the other biaxial islands. This will be rendered clearer by reference to the diagram, which is drawn in proportion. The line *a d* in No. I. will represent the base of the two mountains as originally formed, while *xx* will denote the lava ducts. No. II. is a section of the island after the first mountains have been broken up and the shore ridges formed; and No. III. is the present section, L representing the coast of Napàli, and N that of Niihau. In the second section the base line *a d* is represented as equalling that at present plus the distance L *a* which is the breadth of Niihau. The circumference has increased but little since the shore ridges were formed.

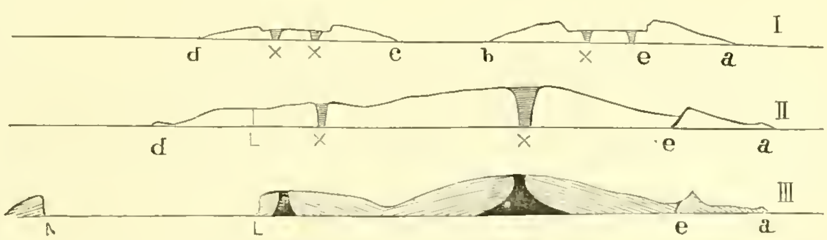


Fig. 46. Theoretical Section of Kauaì.

The strata of these shore ridges all exhibit a dip towards the sea from the mountain, exceeding that of Waíaleale, and are undoubtedly older, as lava beds from the latter have penetrated their cracks. Dykes occur in the ridges in various places, always radial from the

[1] The natives have a tradition that two of their gods were once fishing on the two extremes of Oáhu, and that their lines and hooks became entangled on the west coast of Kauaì, and the gods pulled so hard as to drag Niihau some distance before the lines broke.

centre Waíaleale, and numerous breaks, so extensive as to divide the chain into several apparently distinct ridges, have the same direction.

The lavas did not reach the surface in a single vent over each axis, as on Háleakala, Mauna Lòa, Kilauéa or Kéa, but were distributed in a number of craters, several of which were simultaneously active as on Hualalaì and Kohála.

The solid, unstratified axis of Waíaleale is a cone with a greater diameter in proportion to its height than that of either Kaàla, Konahuanùi or Eéka, indicating either an intenser heat or a longer period of activity. From the greater horizontal extent of this solid core, Kauaì retains more moisture on the surface and has thus become more decomposed through the superficial strata that mark the successive overflows of lava; and its compact summit, almost constantly bathed in clouds, collects and retains enough water to form swamps and springs, the sources of large and constant streams whose rapidly descending currents are still enlarging the ravines and valleys they have hollowed out on all sides of the mountain. Vegetation has been promoted, and in turn has decomposed the rock, forming earth which will retain water, so that now, from the base to the summit, Waíaleale is clothed with verdure, and its middle slopes are covered with large and ancient forests. In taking denudation as an index of age, regard must of course be had to the material acted upon. The greater the height, and the steeper the slope, the more transporting and wearing power will the water have; the more compact the rock the more water will be retained to form streams; and if the rock in the upper regions is easily detached in blocks, a grinding and cutting machine is supplied of which water is only the motive power. As the hard boulders cut out the pot-holes in the bed of a stream, so the rough, freshly broken masses of hard basalt from which the rounded boulders are formed, cut and tear away the softer strata which have been in succession the surface of the mountain, and even cut deeply into the very core which is composed of their own material. The rock of the summit of Waíaleale is a very hard clinkstone, which is brought down in the numerous torrents, and is found in rounded boulders blocking the bed in the mile or so of nearly level course near the shore. The erosion is almost visible from day to day, clearly from year to year. On Mauna Lòa the rock is porous, the core is not proportionally thick, and the rains form no single stream, and of course there are no water-worn valleys.

The beach sandstones near Hanaleì are buried from eighteen to twenty-four inches beneath the surface by the deposit of the river which extends over many square miles, but this is the only case on the island where anything like a delta is formed by fluvial deposits. Even during the storms, when the streams are swollen and the bed is worn away to a considerable extent, the waters are not remarkably muddy, and they become quite clear as soon as the freshet begins to subside.

The evidences of elevation on Kauaì are by no means so satisfactory as on Oáhu. The so-called *raised reef* near Kolòa, I am satisfied, is only a consolidated dune of coral sand; and all the sandstones on the shores may easily have been formed in their present positions. The fact that the water near the shores is becoming shallower, only shows that the deposits washed down from the mountains are not removed by the waves as fast as they form. I did not see any marks of subsidence.

The interior elevated regions of Kauaì will doubtless reveal to the future explorer many interesting geological facts; no other island of the group promises so much, but like northern Hawaii the rank vegetation and difficult ridges and ravines make the exploration no easy task. From the reports of natives, we learn that there is much very fertile land on the plateaus which might be rendered accessible by roads cut through the thicket. Should the islands ever be annexed to the United States, American enterprise, with American capital, will doubtless utilize these now savage and deserted tracts.

Oáhu. — As on Kauaì, the lava has issued from two centres, but the vents were not clustered around two points, thus forming a symmetrical peak, but are arranged in two lines parallel to the general trend of the group; resulting in two mountain chains.

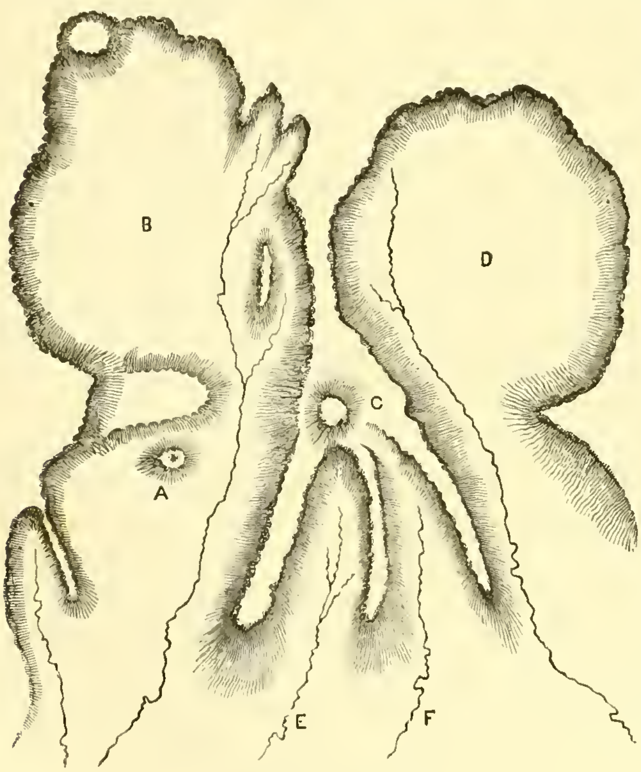
At some period of its history Oáhu must have suffered from vast forces tending to rend its mountains, which however acted in a quiet way as when Mauna Lòa is broken to admit the passage of lava. The result has been a detachment of a portion of the northern slope of the eastern or Konahuanùi ridge, and this fragment has wholly disappeared. I cannot with Prof. Dana consider the missing portion so large that the remaining mountain is but a small part of the original mass. He had never seen the line of craters extending through fifteen miles along the centre of the Konahuanùi Range. Kaneóhe Point was perhaps the immediate result of the great rupture; the engulfed portion has made shoal water to the distance of a mile and a half from the shore, and the lavas from the crack piled up the craters of Kaneóhe and the various islands along the coast.

Sinking Oáhu two hundred feet makes a very great change in its topography, and seems to explain many puzzles. There are then two islands; the cliffs almost perpendicular on the Koolaù side are washed by the waves that drive against them on the windward side; the rounded cones of Kóko are under the waves, and Leáhi is an island half a mile from shore; the currents and winds strike its tufa walls, and it is slowly washed away on the windward side. On the south of the island of Konahuanùi is a series of deep bays from Palòlo valley to beyond Kalìhi, on the west. Puawaìna is on the shore, while Aliapaakaì is almost submerged, its material being swept away by the currents to form the extensive shoal of Laelóa. The Kaàla mountains form an island similar in most respects to the Konahuanùi, but being on the lee side are less exposed to marine erosion.

What are the indications that this picture of Oáhu is outlined from fact? The rounded cones of Kóko are perhaps a more striking proof than even the raised coral reef which extends nearly around the island. That tufa cones are sometimes thrown up on land with a rounded summit I do not deny; but a crater is always present in such cases. Even the winds and meteoric influences generally do not obliterate it; submarine currents alone do that when the cone is growing, or at least before it has become cemented by meteoric influences. The plain between the two ridges is however the most conclusive proof. Fine natural sections are exhibited in the bed of the several streams which traverse it in very winding courses, and there we see broad beds of alluvial deposit of uniform thickness, which were undoubtedly formed beneath the water. Above these however are irregular bands of varying thickness extending to the surface, evidently subaërial in their formation. Indeed, every severe storm adds to their number, when the mountain torrents invade the plain and tear away from one portion to pile upon another, or break down from the mountains by other than their usual routes, carrying with them earth and rocks. The upper level of the submarine beds is from a hundred to a hundred and seventy-five feet above the sea. Fragments of coral are found in them, and a careful search would probably reveal shells

The erosion of the sea-walls of Puawaìna and Leáhi, the former now some distance from the shore, can hardly be due to pluvial influences alone; the material of Puawaìna is too evenly spread over the elevated reef which forms the foundation of the city of Honolulu. I am much inclined to the belief that Oáhu has been elevated nearly two hundred feet since the coast craters were formed.

Whether this elevation was gradual and long continued, or spasmodic and extensive, is not easily determined, for the steps in the ancient elevated reef which would seem to indicate the latter, may have been formed by subsequent earthquakes, and there are no distinct terraces or ancient beaches to be traced around the island. Molokaì is the only other island which bears evident signs of elevation, and on examining these two islands, it seemed as if the axis of Konahuanùi was not vertical but inclined towards the north-north-west; or that the island of Oáhu had been raised at the south-eastern end nearest Molokaì much higher than at the opposite side. On Molokaì the appearance was still stronger, but owing to the removal of nearly the whole of the windward slope on both islands it is perhaps impossible to determine by measurement whether this inclination of the mountain axis really exists. Certainly one shore appears to have been elevated more than the other. Possibly the eruption which cracked Konahuanùi and opened the Nuuánu and Manóa craters, formed Leáhi and the other coast craters, and inaugurated the elevation of the island.



Map of the Valleys near Honolulu.

A, small cone in Nuuánu; B, circus of Nuuánu Valley; C, smooth conical peak; D, Manóa Valley; E, stream from Pauóa Valley; F, stream from Makiki Valley.

The lineal arrangement of craters has not been before noticed on Oáhu; indeed, few explorers have had the time required to scale the sharp ridges and penetrate the dense jungle of the valleys. Manóa and Nuuánu have already been referred to as craters, and their shape will readily be seen from the sketch-map (Fig. 6), where B represents Nuuánu, D Manóa. Precisely similar to these are the valleys west of Kalìhi, and at Punalúu a complete cone crater is found. The nature of the Konahuanùi Range precludes the possibility of a longitudinal path, and the explorer must ascend every lateral ridge, a toilsome journey.

On the Kaàla Ridge many of the ancient craters are now marshes or ponds, and the same is true of Konahuanùi to a less extent.

Earthquake throes usually vibrate from the mountains to the sea on all sides of Oáhu, perhaps indicating a solid axis over a fissure not yet wholly cut off from internal commotions.

Molokaì. — This island was formed much in the same way as Oáhu, by the union of the overflows of two linear vents. The western part never attained the dimensions of a mountain, and bears many tokens of having been wholly formed beneath the sea, while the eastern Mauna Olokùi has suffered a fracture similar to Konahuanùi. The precipice left by the rending apart of the mountain is steep and like that of Koolaù, and at the bottom is a plain of pahoehoe containing many cones and craters of comparatively recent origin. Like Oáhu, Molokaì has been elevated above the sea considerably, probably from three to five hundred feet.

Lanai. — While Oáhu, Molokaì, and Hawaii present high precipices to the windward side, Lanai slopes from a vertical wall on the lee side, that is to say, a break has occurred nearly parallel with that on Oáhu, but in this case the opposite side has fallen. No series of soundings have been made off these islands, but the water is deep, and the break seems to extend some distance below the surface ; but this is mere conjecture.

Máui. — Much like Kaàla at its western end, Máui in its great Háleakala closely resembles Mauna Lòa. Eéka is much broken through, and its ancient craters are now extensive valleys. The whole mountain is so pierced that a tunnel a quarter of a mile in length would connect the two sides.

Hawaii. — The formation of this island has been traced in the successive outpouring of its lava-streams, and we may turn at once to the consideration of the action of lava as exhibited in the volcanoes of this group.

Lava as a formative Agent.

The lava rises to the surface and overflows, forming a bed of lava of a thickness proportionate to the level of the ground ; the action is always intermittent, and as it diminishes the lava cools ; another discharge increases the thickness of the layer, and where following the first without the intervention of scoriæ, ashes, or decomposition, may unite completely with it, forming one bed. Where scoriæ intervene, the two deposits are separated by a distinct line. In this way we may have beds of eighty or a hundred feet in thickness, and as the surface around the discharge is at first tolerably level, or has been made so by subsequent eruptions, the lava will flow in all directions slowly, and form such uniform beds as are seen in many places on the islands. Discharge succeeds discharge, and the mountain is raised up around the orifice from which the lava flows. As the lavas are liquid, they will flow away from the central opening, forming a gentle slope quite unlike the cinder cones, where the material must remain nearly where ejected, until the angle of its sides becomes too steep to retain additions. Consequently while cinder cones may have an angle of 40°, lava cones seldom exceed 10°. The specific gravity of the lava exercises a considerable influence in determining the angle at which its streams will consolidate, and thus the slope of the mountain. The Hawaiian lavas contain much iron and augite, and the dome formed is quite flat.[1]

Each succeeding stream melts into the previous ones, unless a bed of cinders or soil interposes their non-conducting properties, and in some cases I have seen recent flows so united with the beds through which they pass, as to render it quite impossible to detect the point where one ended and the other commenced. The more rapid the motion of a lava-stream,

[1] See Scrope *on Volcanos*, p. 131.

the deeper it burns into the subjacent rock, acting, if I may use the comparison, like a soldering iron which may often be held against a stick of solder for some time without melting it, when the motion of rubbing would liquefy the metal at once. Examples have been mentioned where this action of a rapidly moving stream has melted into the lava beds over which it passed, to the depth of even two hundred feet. This was the case in the long-continued flow of 1855 from Mauna Lòa, and the apparent fissures are often as much the result of this action as of a forcing apart of the mountain side, and they often mark the site of a future valley.

Each overflow from the central vent will form a rib or buttress covering a segment of the mountain more or less extensive, imparting a vast strength to the walls and permitting the rise of the lava within, until its pressure breaks through the walls and escapes in a lateral eruption. These side outflows are of frequent occurrence in various volcanic domes, and may arise from a rending of the whole mountain, — or the opening of a small fissure; in the former case strengthening the wall by an interlacing dyke, in the latter usually rendering it cavernous. All the recent discharges from Mauna Lòa have been of the latter kind, and occur at nearly the same elevation. A small fissure opens, which gradually widens as the flow progresses, until the stream leaps forth in its full strength. It is a noticeable fact, that never has the rending of the mountain been perceived by earthquakes or tremblings. "A small beacon fire" announces the opening of a *small* crack, which opens as gently as the cracks in drying clay.

The eruption of 1840 from Kilauéa made a more extensive crack, and no subsequent eruption has taken the same direction.

Within the mountain the tube of lava which supplies the summit crater, protected in great measure from a loss of heat by the outer wall, melts during its periods of activity into the sides of the mountain, becoming a conical reservoir of lava which will have a greater or less diameter at its base in proportion to its activity.

It is probable that a mass of melted lava, fluid and comparatively quiet, will experience a change in composition at different levels, by a separation of the different minerals mechanically united in its mass, according to their different specific gravities. Thus trachyte and the feldspar lavas, will, owing to their low specific gravities, rise to the top, and the heavier augitic lavas fall towards the bottom. The specific gravity of trachyte is 2.4 – 2.62, while that of augite is 3.23 – 3.5, a difference quite sufficient to cause a separation if other circumstances admit.[1] That the top of the cone will be all trachyte and the bottom all basalt must not be supposed, for the constant currents prevent a complete separation, and all varieties and all proportions of admixture will be found at different heights. This is the view taken by Mr. Darwin,[2] as well as by Prof. Jukes and Mr. Scrope.

After a separation of this nature, which doubtless requires time, if the lavas rise and overflow the edge, trachytic streams will be poured out; and in support of this view we find that all the summits of the Hawaiian volcanoes are more or less trachytic, or at least feldspathic.

[1] See Scrope *on Volcanos*, p. 110.

The specific gravity of volcanic minerals is as follows: —

Orthoclase	Feldspar	2.4 — 2.62.
Albite	Feldspar	2.59 — 2.65.
Oligoclase	Feldspar	2.58 — 2.69.
Leucite		2.483 — 2.49.
Quartz		2.5 — 2.8.
Mica (hexagonal)		2.7 — 3.1.
Hornblende		2.9 — 3.4.
Augite		3.23 — 3.5.
Garnet		3.15 — 4.3.
Olivine		3.33 — 3.5.
Hæmatite		4.5 — 5.3.

[2] Volcanic Islands, pp. 118–124.

If a break occurs near the base the lavas will contain more augite, as the lava-stream which formed Aliapaakaì on Oáhu, where crystals of augite are quite common. Intermediate vents will pour out a lava of a mixed composition, and of this nature are most of the Hawaiian lavas. But this is the rule only when an eruption has been preceded by a long period of rest.

It is a mistake to adopt the theory that formerly trachytic, and now basaltic lavas are ejected. In many volcanoes basaltic underlie trachytic, and lavas of all gradations between the two are found at different ages of the same volcano.

There is another cause of the variety of eruptions from the same mountain, in the separation of minerals of different fusibility. Ferruginous minerals may be volatilized, leaving in one place a lava destitute of iron, while in another the lava is highly ferruginous; or they may line the cavities of the upper mass with specular iron ore, as at Elba.

M. Daubrée has shown that the concurrent influence of heat and pressure will form crystals of augite, feldspar, quartz and mica from water containing alkaline silicates in solution with common clay;[1] and it is not at all improbable that the frequent melting and hardening, the great heat and pressure on the mass of lava, may cause the crystallization of its elements into new mineral forms. It is certain that such crystals are formed in the interior of the mountain and ejected in an undecomposed condition. Mr. Darwin saw in Albemarle Island a stream of black lava thickly studded with large fractured crystals of albite, many of them half an inch in diameter, which he says were evidently enveloped and penetrated by the lava and rounded by friction as the stream flowed on. MM. Monticelli and Covelli describe a lava ejected from Vesuvius in 1822 as containing leucite in the proportion of six to one of the other ingredients. The granules were melted on the surface.[2]

The Hawaiian lavas contain much olivine, a very refractory mineral; and where the stream has issued from a considerable depth, as in the eruption from Kilauéa in 1840, it is in large granules and very abundant. Its specific gravity, it will be remembered, is 3.33 – 3.5. In the ejections from the summit it is in minute particles, as if broken and carried up by the currents in the melted mass. M. Von Buch has remarked of the basaltic lavas of Lancerote (and Mr. Scrope has observed the same in those of the Eifel and the Vivarais), that while the nodules of olivine are large near the source of the current, they dwindle away towards the extremity so as to be scarcely visible.[3]

In the lava-stream of Aliapaakaì, before mentioned, the eruption took place after a long period of rest, and from a considerable depth; and the lava contains large nodules of olivine five or six inches in diameter. The same is seen in the lava of Kóko, a similar formation, where crystals of augite also occur.

The separation of the less fusible portions of melted lava is well shown in the formation of a-a which is simply a sort of imperfect crystallization of the parts of the lava first cooled, from which the mother liquor, the still liquid lava, has been suddenly drained by the removal of the dam which blocked the stream.

When the volcanic action ceases or becomes extinct, the conical mass of lava cools slowly, and forms a mass wholly destitute of stratification. This fact was noticed in the volcanic islands of the Pacific by Prof. Dana, and it is in these islands that the inner core of the

[1] See Daubrée, *Études sur le Métamorphisme*, Paris, 1859.

[2] *Monticelli e Covelli. Storia de' Fenomeni del Vesuvio*, Napoli, 1823.

[3] Scrope *on Volcanos*, p. 119, (2d ed.)

mountain may be best examined, as the denudation has exposed it in all the deep valleys so common on these high islands.

In these valleys I have been able to examine the solid nucleus of Mauna Kéa on Hawaii, Eéka and Háleakala on Máui, Olokùi on Molokaì, Konahuanùi on Oáhu, and Waíaleale on Kauaì, and I find the general appearance of all these cones to be the same, compact and unstratified; but the kind of rock at the summit varies slightly. On Waíaleale it contains less feldspar, and is more uniform, as if no opportunity had been allowed for it to settle: Konahuanùi has more feldspar, and portions of its rock much resemble syenite: Olokùi and Eéka almost the same; while Háleakala and Kéa are quite feldspathic, and the former has streams on its flanks of highly feldspathic lava. Olokùi contains much iron on its summit overflows (not in its core), as does also Konahuanùi, while on Waíaleale there are said to be large deposits of ferruginous lava. The base of the cones in all cases is basaltic, so far as exposed. It may be added that the summits of Maunas Lòa, Hualalaì, and Háleakala are all largely composed of trachyte or a phonolite closely approaching it.

In Waíaleale, Eéka, Konahuanùi and Olokùi then, the composition of the cone is tolerably uniform, while on the other mountains various gradations between trachyte and basalt may be traced. The mass of these mountains is not sufficiently different from each other to lead us to suppose that a different period of cooling after the action ceased has caused the different distribution of elements which seem to be the same in all; and we cannot believe that the different lavas have been produced at different times, for it is impossible to draw any line of demarcation, so closely do the intermediate greystones connect the trachytes with the basalts. I infer from this that the mountains which produce the most uniform discharges, are the most active ones, and that when a volcano enjoys a long period of rest, its lavas will present greater variety. Kilauéa and Mauna Lòa are at present in a constant state of activity, and their lavas have comparatively no rest, and the eruptions are nearly uniform. Vesuvius is exceedingly irregular, sometimes bursting forth after a repose of nearly two centuries, and its lavas are more composite than those of any other known volcano.

Angle at which Lava flows.

M. Dufresnoy declares that lavas, to be compact and crystalline, must have cooled on a slope of less than 3°.[1] This statement has been proved incorrect by Sir Charles Lyell in his valuable "Memoir on the Lavas of Etna,"[2] and on the Hawaiian Islands slopes of every degree of inclination occur. I have measured streams that have consolidated on angles of from 10° – 90°, and in all cases they were continuous. Rev. Mr. Coan has done even more, and I quote his own words: "On the mountain and in Kilauéa I took the angles of several lava-streams, one of 49°, another of 60°, and two of 80° each, several streams on the mountain flowed down banks of scoriæ twenty-five and thirty feet high. The fusion was complete — the streams cooled in a perfect state.

"I saw thin strata, say one inch thick or less, which had flowed down the face of perpendicular rocks, adhering to the rocks like paste, and thus cooling. Will you say that I spoil my demonstration *by proving too much*, when I assert that I saw more than one place where the lava flowed at an angle of 95° — like the Indian's tree which grew so bolt upright

[1] "Les coulées, qui se présentent sous un angle de 4° ne sont plus que des agglomerations de fragments incoherents." *Terrains volcaniques des environs de Naples*, iv. 342.

[2] *Philosophical Transactions of the Royal Society*, part ii. vol. cxlviii. for 1858.

that it 'leaned the other way,' — thus flowing down a bank until it came to where the rock *retreated*, it would follow the inward curve in a thin layer like molasses, adhering to the rock and thus cooling."[1]

I have myself seen precisely such cases as Mr. Coan describes, and the consolidated lava often looks like mud slowly oozing through the cracks and down the surface of a perpendicular wall. I have seen a bed of lava several feet thick and quite compact, which had solidified at an angle of 35°. Cases have been cited where the lava has flowed over a bank in a thin stream which has formed layer after layer until the angle has been reduced to 3°.

Cooling of Lava.

It has been shown that the lava cools very rapidly on the surface, so that a stream may be walked upon a few hours after it has been incandescent. The lava on the surface of the Halemáumau crusts over almost instantly after the action ceases, and the fragments of lava thrown into the air cool almost before their rapid motion can change their form. Instances have been cited where the lava, dashed upon a tree by a passing flow, has consolidated in rings around the branches without burning into the bark. The casts of the trees, occurring quite through a bed twenty feet thick, show that where the caloric can escape through any good conductor the lava becomes solid. The crust is however a most excellent non-conductor, and under its protection the lava may run for months, or remain heated for years. The flow of 1810 was steaming for more than ten years after it ceased to run, and while the other recent flows have cooled in a much shorter time, it is owing to their being quite thin and cracked.

The more rapidly lava cools the more vitreous will be its texture, as is shown in the Pélé's hair, in the drops of lava thrown from the lake into the air, which are as vitreous as obsidian, and in the surface of lava-streams. I obtained many specimens of crust from the wrinkled streams, and while the inside was quite porous, the outer surface, to the depth often of half an inch, was quite compact and vitreous, as will be seen from the impression of a section of crust. The lava poured out of the pools in Kilauéa, and some of that in the summit eruptions, cools very rapidly, and the whole surface much resembles the thin glass flakes produced in the process of stamping bottles at a glass-house. Where melted lava is thrown into water, it is broken and granulated into a glossy coarse sand or gravel.

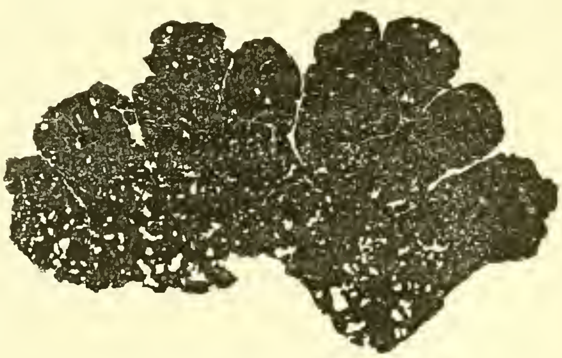


Fig. 47. Impression of lava crust.

The temperature of the Hawaiian lavas has never been determined, although from their extreme liquidity it is probably very high.

Formation of Pit Craters.

Kilauéa, and the similar craters on Maunas Lòa, Hualalaì, and other mountains of the group, are simply orifices left by the overflowing lava, and by no means the remains of

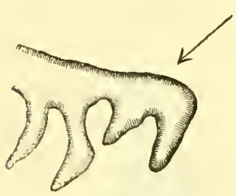
[1] Silliman's *Journal of Science*, [N. S.] vol. xxi. p. 142.

collapsed bubbles, as Mr. Scrope and others seem to think. They have not been formed by a falling in of the top of the mountain, but the process is this: When the lava subsides in the tube after a surface overflow, it leaves a well or depression, which will have perpendicular walls. A violent commotion in the lava at the bottom of this pit at a recurrence of volcanic activity will crack and dislodge portions of the wall, which will be swallowed up in the melted mass. The lava may again rise and overflow the rim, and its heat will both melt and crack the walls, and thus the crater of an active volcano of the Hawaiian type constantly increases in diameter. When the lavas no longer overflow, they may yet reach the base of the encircling wall and remove the debris, which falls, maintaining the perpendicularity of the cliffs. This has been the case at Kilauéa, and the fragments broken from the upper walls now form a low ridge some distance from where they fell, having been transported by the fiery currents. The natives declared to Mr. Ellis, on his first visit to the crater, that it had grown much since ancient times.

Neither in these craters nor anywhere on the mountains can I see any signs of "a single, sudden swelling up of previously formed horizontal beds of lava and scoriæ into a hollow bladder."

Influence of constant Winds.

The north-east trades blow during nine months of the year with considerable force, and their influence is seen in the tufa cones which always are higher and broader on the south-west, as the comparatively light tufa is easily blown by the winds. But in the ridges themselves there is a curious feature which probably owes its origin to the cooling influence of these winds. The general direction of all the spurs is from the north-east. The windward sides of the islands usually present perpendicular precipices, or short steep ridges where the islands are broken, as in Oáhu and Molokaì, while Hawaii presents to the force of the waves, unbroken by any protecting coral reef, a precipice several hundred feet above, and at least as many below the sea level.



Makapùu Ridges.

A direct result of a constant direction of the wind is the more rapid decomposition of the walls of the smoking crater by the action of the sulphurous vapors, causing a crumbling of the walls when the action is long continued.

Earthquakes not a necessary concomitant of Eruptions.

It has been remarked that the eruptions of Mauna Lòa are wholly unaccompanied by any great commotion of the earth. While earthquakes do occur on the Hawaiian Islands, they are never severe, and seldom are noticed during an eruption. They seem to confirm Mallet's theory of vibrations, as they almost always radiate from the solid axis of the centre of an island. A slight shock was felt on Oáhu in the winter of 1865, when the vibrations were distinctly felt from the mountain to the sea on all sides of the island.

[The remarkable difference in level between lavas in the same mountain will be considered in the Topography of Kilauéa.]

Sea Waves.

It is not unusual, during littoral or submarine eruptions, for the sea to be agitated by great and unusual tides. Such sea waves have not attended the recorded eruptions of the

Hawaiian volcanoes, but have been observed on these shores at times when the volcanic vents were not unusually active.

The first recorded took place in May, 1819, when the tide rose and fell thirteen times in the space of a few hours. The elevation was not very great, nor was there any earthquake shock on the land. On the 7th of November, 1837, a more remarkable commotion took place. At six o'clock the sea retired to a depth of eight feet, leaving the reef surrounding the harbor of Honolulu quite dry. The water then slowly returned, and in twenty-eight minutes had risen to the height of an ordinary high tide. Without a pause it again fell six feet, and this ebb and flow was repeated at intervals of twenty-eight minutes. At the third flow it rose four inches above ordinary high-water mark, and fell again six feet four inches. After the fourth flow the motion became irregular and gradually diminished, but did not return to the ordinary course of the tides until the next day. The meteorological observations do not show any extraordinary disturbance in the atmosphere.[1]

11 P. M.	Thermometer	74°.	Fahr.	Barometer	30.04.
11.30 P. M.	"	73.5°.	"	"	30.03.

At Kahulùi on the windward shore of the Isthmus of Máui, the sea retired suddenly twenty fathoms. The natives followed with delight picking up the stranded fish, when suddenly the water rose like a wall before them and overwhelmed them in a wave which swept up on the shore destroying the village. Happily only two lives were lost here, as the people were quite at home in the water. At Hìlo the first fall of the water took place at half-past six, half an hour later than at Honolulu, and the returning wave rose twenty feet above high-water mark.

May 17th, 1841, a similar although less violent commotion of the sea took place. In the harbor of Honolulu at twenty minutes past five P. M., the water was observed to be "discolored and breaking like a tide rip." It then fell rapidly, leaving the reef and portions of the harbor bare. Twice during forty minutes this ebb was observed, and the sea then assumed its ordinary appearance. At Lahaìna, nearly a hundred miles distant, the first ebb was almost simultaneous, but the rise and fall was quite rapid, at intervals of four minutes. It is said that a similar sea-wave occurred on the coast of Kamtschatka.[2]

The effects of such waves in undermining the cliffs along the shore must be very great, and it was perhaps during one of these extraordinary tides that the loose craters on the shores of Ka-ù were partially demolished; certainly the cliffs were broken away in that district by this means, and I am inclined to attribute to the same powerful agent erosions on the lee shore of the other islands of the group.

Magnetic effects of melted Lava.

It would be most interesting to try the effect of a lava-stream in motion on the magnetic needle. In the vicinity of the Halemáumau in Kilauéa the needle of the theodolite compass was strongly affected, and the variation at the different stations on the upper bank was considerable but inconstant, doubtless owing to the presence of moving lava currents, as the disturbance was most marked in the vicinity of the pools. In several cases the variation has been noted on the map of Kilauéa. (Pl. XV).

[1] *Hawaiian Spectator*, vol. i., p. 104. Observed by Dr. T. C. B. Rooke.

[2] Jarves's *History of the Hawaiian Islands*, p. 22.

Erosion.

The effects of erosion have been considered evidences of the age of the Hawaiian mountains, and it would be well perhaps to examine the extent to which rains, rills, and rivers rushing rapidly, rend rocky regions, remove rock remains, leaving lofty ledges, perpendicular palis or precipices, and in a word work wonderful changes in the smooth, swelling summits of these volcanic islands.

The original form of the mountains was probably quite similar to that of Mauna Lòa — smooth rounded domes; but the present aspect is, as we have seen, quite different. Wherever the trade winds have driven the rain clouds against the mountains, streams have formed, and while at first they have been absorbed by the porous lava and carried by subterranean paths to the sea level, the decomposition of the lava produced by constant moisture has at last formed a soil capable of retaining surface streams. The nature of the rock has much to do with the rapidity of this process, and the shape of the central compact core is not without its influence. The continued rains, finally retained on the surface until they have acquired sufficient volume to form brooks, commence the erosive process.

Mauna Lòa is smooth; no rivers run over its slopes, and its only ravines are the work of streams of lava or the earthquake. The same is true of Hualalaì, and both these mountains are on the leeward side of the island of Hawaii. A glance at the map (Pl. XIV.) will show their position, and also that of Mauna Kéa and Mauna KoháIa, whose peaks almost entirely intercept the vaporous clouds which the constant winds bring from the ocean. The windward slopes of these latter mountains are deeply channelled by the permanent streams and frequent freshets, while on the south and west they are as smooth as the sides of Mauna Lòa. The gorges on Mauna Kéa from Hìlo to Laupahòehoe, are both numerous and deep, and indicate as long continued erosion as those on Kauaì. Many extend more than half way up the mountain through the dense forests on the north-east, and while some, as that at Laupahòehoe, have been worn down to the sea level so as to form valleys of considerable extent, the majority meet the ocean in a fall of several hundred feet on the very shore. In all these cases the rock is essentially of the same nature and arrangement; and where the streams are of equal size, the height of the fall is about the same, indicating curiously enough the synchronous origin of all these streams. At Laupahòehoe, the stream is not very large, but there are indications of earthquake rents which assisted the eroding waters. I was unable to examine this valley as I could have wished.

On Máui (Pl. XIII.) the windward portions of Háleakala, comprised in the district of Hána, are grooved in the same way as we have described them on Kéa, but like the mountains of Hawaii the destroying valleys have not yet reached two thirds of the height of the summit. The leeward slopes are not eroded. Eéka is lower, and the torrents have completed their work on the north-east, and have even invaded the other sides, until, like the Tahitian mountains, only a skeleton is left. This result is owing to the depth of the craters and their shattered walls, as well as to the streams of water. These cavities were so deep that they penetrated the solid core of the mountain to a considerable depth, and thus retained water to supply streams.

On Lanai and Kahoolάwe (Pl. XIII.), the ravines are not the work of surface streams.

This I infer from their presence mostly on the leeward side of the islands which are themselves on the lee of Máui, and also from the entire absence of running water even in small quantities; the severest rains even hardly form a brook. Molokaì has been eroded by both sea and rivers. The eastern end at Halàwa is undoubtedly worn by waves when at a lower elevation than at present, and the same agent has removed the windward slopes. On the south side the valleys are not deep, but exceedingly irregular, and often bear marks of the severe freshets that sometimes occur during certain winds. In many cases the streams which have formed the ravines seem ridiculously inadequate to the immense task of excavating the great valleys through which they quietly flow, but these occasional torrents explain the true agency. The craters on the summit of the ridge are the usual sources of the permanent streams which run, almost without cascades, to the sea. This general absence of cascades of any considerable height, — there are several at the eastern end which may compare with some on Hawaii, — characterizes this island.

Oáhu presents many of the features of Molokaì (Pl. XII.), and is eroded by the sea on the windward side, while on the south-west of the Konahuanùi range the valleys cut into the heart of the mountain. In speaking of the origin of Oáhu, attention has been called to the linear craters and their broken walls. Nuuánu has been cited as an example of a crater completely broken through on both sides. Manóa was also in all probability opened towards the south by the final eruption, and the waters have only had to enlarge the rent thus formed for their passage.[1] The Kaàla range is only eroded on the windward side and does not present deep valleys.

Kauaì (Pl. XI.) is deeply channelled on both windward and leeward sides, and the ravines reach deep into the core of the mountain; indeed, the Hanapépé and Waiméa valleys are deeper and have more precipitous sides than Hanaleì, Wainìha, and Lumahaì on the north. From the flat and crater-crowded summit the overflow of the marshes which abound there winds down on all sides; the Hanaleì and Hanapépé rivers rising from the same swamp and flowing in exactly opposite directions.

On all the islands the effect of destroying the timber has been very marked. On Oáhu especially the rainfall has been much diminished on the mountains, and the little stream in Nuuánu valley which supplies Honolulu with water is greatly wasted. The introduction of goats and cattle which run loose on the mountains destroying the young and tender shoots of the ohia and koa, the principal trees, and the wasteful and improvident way in which the natives destroy wood, has converted portions of the once moist and wooded mountains into dry pastures where the indigo alone of shrubs flourishes. Should the government take no measures to stop the wanton destruction of the forests, Oáhu may become like Niihau or even like Lanai. It would be instructive to present the annual rainfall since the introduction of goats, but no accurate observations have been kept regularly, although the zeal of amateur meteorologists has been awakened from time to time, especially at the Punahoù school. In 1837 and 1838, Dr. T. C. B. Rooke kept a careful register of atmospheric changes, from which it will be seen that at Honolulu, the thermometer and barometer were tolerably constant through both years while the winds varied considerably and the rainfall was more than doubled in the last year. During the rainy season of 1864–65, the following measurements were taken; —

[1] For an admirable explanation of the formation of valleys see Dana's *Manual of Geology*, p. 635; also *Exploring Expedition, Geological Report*, p. 290, and Silliman's *Journal* [N. S.], vol. ix., pp. 48 and 289.

Punahoù.[1]				Nuuánu Valley.[2]			
Dec. 1 . . .	.013	Dec. 8 . . .	.207	Dec. 4 . . .	2.80	Dec. 13 . . .	1.50
" 3 . . .	.024	" 13 . . .	2.950	" 5 . . .	.35	" 14 . . .	4.50
" 4 . . .	1.052	" 14 . . .	3.921	" 6 . . .	6.00	" 15 . . .	8.25
" 5 . . .	1.215	" 15 . . .	4.499	" 7 . . .	2.10	" 16 . . .	12.00
" 6 . . .	.833			" 8 . . .	.45		
" 7 . . .	.486		15.200	" 11 . . .	.08		38.03

At Punahoù, from the twelfth to the nineteenth of February, the rainfall was as follows:—

In the morning,	13th	14th	15th	16th	17th	18th	19th
inches,	.496	.480	.099	.698	.080	.408	.050 — Total, 2.311 inches.

These were my own measurements. Dr. Rooke's table is as follows: [3] —

Time.	Barometer.			Fahr. Thermom.			Winds.			Weather.			
	Average height at 7 A. M.	Average height at 2 P. M.	Average height at 10 P. M.	Average at 7 A. M.	Average at 2 P. M.	Average at 10 P. M.	Trades — Days.	Kóna — Days.	Variable—Days.	Fine — Days.	Rainy — Days.	Variable—Days.	Rainfall, inches.
1837.													
January . .	29.970	30.006	30.043	69.9	76.6	71.3	10	14	7	24	3	4	2.0
February .	30.076	30.030	30.060	71.1	77.7	72.7	22	4	2	19	3	6	1.7
March . .	30.098	30.057	30.087	69.6	76.6	72.4	19	6	6	22	2	7	2.5
April . .	30.128	30.092	30.117	72.1	78.4	73.7	30	0	0	25	4	1	1.2
May . . .	30.109	30.085	30.097	73.4	80.2	75.0	30	1	0	29	1	1	0.9
June . .	30.093	30.081	30.085	76.1	81.9	77.5	29	0	1	21	3	6	1.4
July . . .	30.115	30.095	30.107	76.4	81.5	77.3	28	1	2	21	7	3	2.8
August . .	30.077	30.086	30.087	76.9	82.8	78.1	30	0	1	22	3	6	2.0
September .	30.095	30.060	30.097	76.5	83.0	77.0	29	1	0	29	1	0	0.7
October . .	30.116	30.076	30.120	74.8	80.6	76.0	26	4	1	28	1	2	0.4
November .	30.070	30.029	30.071	72.7	77.9	73.8	19	7	4	18	8	4	4.5
December .	30.124	30.072	30.115	69.9	76.5	71.1	23	6	2	27	1	3	1.0
Average . .	30.128	30.060	30.090	73.1	79.5	74.8	295	44	26	285	37	43	21.1
1838.													
January . .	30.060	30.028	30.054	69.3	75.6	71.5	21	5	5	25	3	3	0.8
February .	30.016	29.970	30.005	71.2	75.3	72.1	20	3	5	18	6	4	8.5
March . .	30.105	30.064	30.095	72.0	75.1	72.5	22	3	6	21	4	6	2.1
April . .	30.127	30.095	30.140	71.5	76.7	72.8	29	1	0	27	1	2	1.0
May . .	30.149	30.139	30.162	73.2	80.3	75.5	25	5	1	28	1	2	0.5
June . .	30.085	30.040	30.090	75.5	81.7	77.1	20	7	3	17	3	10	2.5
July . . .	30.091	30.068	30.092	76.4	82.5	77.9	26	3	2	24	3	4	1.5
August .	30.078	30.052	30.078	77.2	83.2	78.4	30	1	0	28	1	2	1.2
September .	30.073	30.035	30.068	76.7	82.6	78.4	27	2	1	25	3	2	2.5
October . .	30.040	30.021	30.142	75.0	80.1	76.9	16	7	8	20	5	6	12.0
November .	30.041	30.008	30.144	72.3	76.6	73.7	18	9	3	19	5	6	6.7
December .	29.978	29.876	29.993	71.5	76.3	73.3	4	25	2	23	6	2	7.5
Average . .	30.087	30.033	30.072	73.5	78.8	75.1	258	71	36	275	41	49	46.8

[1] The measurements are taken at 7.30 A. M. Average temperature 72° Fahr. Winds violent from the north, followed by a calm, and variable south and south-east winds.

[2] Taken each day at 8 A. M., by Dr. G. P. Judd.

[3] Jarves' *Hawaiian Islands*, p 15. The temperature at Lahaina on Máui during ten years ranged between 86° and

In addition to the severe rains of the tropics, water-spouts have from time to time broken in the mountain valleys, and flooded the plains near the shore. Native traditions are full of such catastrophes, and a number have, within the last half century, visited Máui, Molokaì, Oáhu, and Kauaì.

Melting snows do not often produce a debacle, owing to the porous nature of the mountain summits. Snow is common on Maunas Lòa and Kéa, not uncommon on Háleakala and Waíaleale, but does not extend down the sides below an altitude of eight or nine thousand feet.

The Place of the Hawaiian Volcanoes in Volcanic Systems.

In endeavoring to ascertain the connection between the volcanoes of the Hawaiian group and other Pacific ranges, most geologists have noticed the parallel linear arrangement of the Pacific insular volcanoes which trend generally north-west and south-east, and have inferred the existence of as many primary fissures in the earth's crust as there are parallel groups of volcanic islands.

The question arose in my mind whether volcanoes presented in themselves any indication of mutual relation other than mere position on the same line. I did not endeavor to connect the periods of activity or eruption, because I have seen so much independent and apparently irregular action in the same vent, as in the lava pools of Kilauéa, or in neighboring vents, as Kilauéa and Mauna Lòa. It was in the shape and position of the craters themselves that I thought the desired clew might be found.

Craters of eruption are almost invariably oval or elliptical in outline, and the usual explanation of this shape is that the ejections which build up the crater reach the surface through a rent in the earth's crust, and not through a circular aperture, or through one formed by a stellate fissure, as would be the case were the superficial strata of the earth's crust raised around an axis to form the so-called craters of elevation. While the fact of the existence of many elliptical craters has long been known, no importance has been attached to the direction of the major axis. As the elongated form is caused by a rent of greater length than breadth it would perhaps be supposed that the major axis would coincide in direction with the volcanic train, or in other words with the primary fissure in the earth's crust over which the craters occur.

The trend of the Hawaiian Group is N. 64° W., but there is no crater on the islands whose major axis is parallel to this line. On the contrary a very interesting parallelism is observed among all the craters, and invariably the longest diameter is north and south, or at an angle of twenty-six degrees with the supposed primary fissure. Kilauéa, Mauna Lòa, Hualalaì, Háleakala, Leáhi, Puawaìna, Aliapaakaì, the ancient crater of Kauaì, all have the same direction, and so with all the craters on the other mountain ridges. Such a deviation from the line on which these craters were supposed to have been formed must have some explanation. Are there in any other volcanic regions like examples? To answer this question we must know the shape and direction of the craters, and this has been almost always neglected in accounts of volcanoes. I give below, however, a list of such as I have been able to determine the position of, from which it will be seen that *the major axes are always at right angles to the mountain chains* in which they are situated. Another fact will be shown, that the Mexican volcanic train of the nineteenth degree north latitude, commencing with

54° with no greater daily variation than 19°. At Waiméa, Hawaii, at an elevation of four or five thousand feet, the average is 64°, the lowest 48°. At Kolòa, Kauaì, 88° to 50°. At Waiòli, Kauaì, 90° to 55°.

Tuxtla on the Gulf of Campeachy, and extending to the Revillagegido Islands some two hundred miles west of the Pacific coast, exhibits this transverse direction most remarkably. Now if this line be extended westward forty degrees it passes through the Hawaiian Islands where the craters also range north and south.

Commencing with the Andean volcanic line, and placing the larger end of each oval crater first, as indicating the larger part of the subjacent fissure, we have the following result: —

Volcanoes.	Volcanic Line.	Major axis of the Crater.
Deception Island	Andean line S.—N.	E.—W.
† Antuco	" " "	E.—W.
† Aconcagua	" " "	E.—W.
† Sangay	" " "	E.—W.
† Sinchulagua	" " "	E.—W.
Antisana	" " "	E.—W.
Pichincha	" " "	E.—W.
Cayambi	" " "	E.—W.
† Mombacho	Central American line N. 55° W.	N. E.—S. W.
† Masaya	" " " "	N. E.—S. W.
† Coseguina	" " " "	N. E.—S. W.
† Isalco	" " " "	N. E.—S. W.
Agua	" " " "	N. E.—S. W.
† Fuego	" " " "	N. E.—S. W.
Tuxtla	Mexican line E.—W.	S.—N.
† Citlaltepetl or Orizaba	" " "	S.—N.
† Popocatepetl	" " "	S.—N.
Istaccihuatl	" " "	S.—N.
Toluca	" " "	S.—N.
Jorullo	" " "	S.—N.
† Colima	" " "	S.—N.
† Kilauéa	Hawaiian line E.—W.	S.—N.
† Mokuawéowéo	" " "	S.—N.
Hualalaì (several craters)	" " "	S.—N.
Háleakala	" " "	S.—N.
Eéka (several craters)	" " "	S.—N.
Leáhi	" " "	S.—N.
Puawaìna	" " "	S.—N.
Aliapaakaì	" " "	S.—N.
Kauaì (ancient crater)	" " "	S.—N.
† Shasta	North American line S.—N.	E.—W.
San Francisco	" " " "	E.—W.
† Mt. Hood	" " " "	E.—W.
† Klutschewskaja Sopka	Kamtschatkan line N. 25° E.	N. 60° W.
† Tolbatsch	" " "	N. 60° W.
† Awatschka	" " "	N. 60° W.
† Wiliutschinskaja Sopka	" " "	N. 55° W.
† Opalinskaja Sopka	" " "	N. 55° W.

† Active volcanoes.

Volcanoes.	Volcanic Line.	Major axis of the Crater.
† Ushiuruyama	Japanese line N.—S.	E.—W.
† Komanartaki	" " "	E.—W.
† Fusiyama	" " "	E.—W.
Usugatalec	" " "	E.—W.
† Wunsen	" " "	E.—W.
Guguan	Bonin line N.—S.	E.—W.
Farallone de Tores	" " "	E.—W. (?)
† Taal	Philippine line N.—S.	E.—W.
† Mayon	" " "	E.—W.
Egmont	Maori line N.—S.	E.—W.
† Tongariro	" " "	E.—W.
Tuhua	" " "	E.—W.
† Putanaki (Edgcumbe)	" " "	E.—W.
Pihanga	" " "	E.—W.
† Ruapehu	" " "	E.—W.
† Rangitoto	" " "	E.—W.
Mangere	" " "	E.—W.
Puketutu	" " "	E.—W.[1]
† Gelungung	Javan line E.—W.	S.—N.
† Papandayang	" " "	S.—N.
† Gunungtenger	" " "	S.—N.
Guevo Upas	" " "	S.—N.
Ararat	Western Asiatic line N.—S.	W.—E.[2]
Aden	" " " "	W.—E.
† Djebbl Tur	" " " "	W.—E.
† Santorini	Hellenic line N. 60° W.	N. 35° E.—S. 35° W.
† Argentiera	" " "	N. 33° E.—S. 33° W.
† Ætna	Latin line S.—N.	
† Volcano	" " "	E. 5° S. — W. 5° N.
† Volcanello	" " "	E. 5° S. — W. 5° N.
† Stromboli	" " "	E. 10° S. — W. 10° N.
† Vesuvius	" " "	E. 8° S. — W. 8° N.
† Solfatara	" " "	E. — W.
Astroni	" " "	E. — W.
Mont Dore	Gallic line N.—S.	E. — W.
Cantal	" " "	E. — W.
Mezen	" " "	E. — W.
† Heckla	Icelandic line N. W. — S. E.	S. W. — N. E.
† Eyafialla Yokul	" " " "	S. W. — N. E.
Myrdals Yokul	" " " "	S. W. — N. E.
† Kotlugia	" " " "	S. W. — N. E.

[1] F. von Hochstetter, *Geologie von Neu-Seeland.*

[2] Abich, *Bull. Soc. de Géographie.* Sér. 4, tom. 1.

Volcanoes.	Volcanic Line.	Major axis of the Crater.
Teneriffe	Atlantic line N.—W.	N. 60° E.[1]
† Chahorra	" " "	N. 60° E.
† Teyde	" " "	N. 60° E.
Cone of 1798	" " "	N. 60° E.
Fuente agria	" " "	N. 60° E.
Palma	" " "	N. 55° E.
Lanzarote (Montana de Fuego)	" " "	N. 55° E.
St. Vincent	Caribbean line N. — S.	E. — W.
† Montagne Pélée	" " "	E. — W.
† Guadaloupe (La Soufrière)	" " "	E. — W.
Mauritius	South-east African line N. W. — S. E.	N. E. — S. W.
† Isle of Bourbon	" " " " "	N. E. — S. W.

The superficial cracks are very much as represented on the Map of the Group (Pl. XII). The circles or ovals enclose the centre vents while the radiating lines indicate the supposed fissures which have given rise to the minor lateral vents and tufa cones. It will be seen that all the smaller cones are referred to some centre, and the interesting parallelism of the connecting lines will be evident. I connect Kaúla with the centre of Púuokapélé, while Lehùa is undoubtedly an offshoot of Niihau. On Oáhu, Laelóa and the Waianaè craters belong to Kaàla; Aliapaakaì, Puawaìna, Leáhi, and Kóko, to Konahuanùi. On Máui, Molokìni is secondary to Háleakala, and the craters near Haliimaìla and Malìko all fall on two lines, one to the north-east and the other to the north. Hawaii presents a very regular system of subordinate cones, all that have been observed ranging approximately on north and south and north-east and south-west lines. The cones behind Hìlo belong to Mauna Lòa, and the Kapóho series in Púna, to Kilauéa.

Theories of Volcanic Action.

I cannot feel satisfied with the various theories which have been proposed to account for volcanic and telluric phenomena. I am not ready to admit that either electric currents or the waters of the ocean are the source of the heat which presents us with melted rock on the surface of the globe. For in the first case we should have more electricity sensible at the outlets of melted matter, while the lightnings which often accompany eruptions are no doubt due to the expansion and condensation of vapor in the atmosphere; the magnetic variations are such as may easily be accounted for by the motion of imperfectly fluid basalt which contains much iron; and both are totally inadequate to the production of such vast results as we witness constantly in various volcanic foci. On the theory that water gaining access to the interior through fissures, causes the liquefaction of rocks through the oxidation of metallic bases, little need be said, as the originator of this theory (Davy) himself abandoned it as untenable. Water may, if it once obtains access to a mass of melted matter, cause explosions and sudden eruptions; but such action must be exceptional, for the instant water approaches an intensely heated mass it assumes the spheroidal state, and no contact takes place. If it be argued, however, that the water would be under great pressure, that under

[1] Von Buch, *Isles Canaries*.

great pressure it can be heated red hot without assuming the condition of vapor, and that sudden motion or changes of pressure, such as we know are constantly taking place in the earth's crust, might bring about a contact, in such a way as to cause an expansion of the water into steam, and cause an elevation of the combined water and melted mass to the surface, we must point to the quiet welling out of the Hawaiian lavas, and ask for an explanation of that.

What we see with these lavas is quite contrary to the supposition that water causes their activity. Often they pass into the ocean and cool rapidly beneath the water; at other times when the motion is violent, the water obtains access to the interior of the mass and cools it still more rapidly, breaking it into sand. Where the fresh water gains access to the incandescent lava the effect is to cool it more or less rapidly in proportion to the quantity of water. Everywhere on the surface the tendency of water is to cool the melted mass by its evaporation, and whatever its action may be at great depths, under great pressure, on being set free on the surface it should cool the mass from which it escapes. There is not enough water set free from any volcano known, to account for the elevation of such vast weights of lava to such great heights. To do the work steam must pass from a high tension to a lower one, and must finally escape into the air. In its high tension it may be condensed to water by extreme pressure, but on reaching the atmosphere it must lose all this tension and become ordinary steam at the pressure of sixteen pounds to the square inch, or unite chemically with the lava. Analyses show us that the last is not the case, and no more steam is evolved from the Hawaiian volcano than must result from the rainfall on the heated surface of the exposed lava. Prof. Dana intimates that the rainfall may be the fuel of the volcano; if so, why should not constant eruption attend a season of rain? I have been on the banks of the lake of liquid fire during a severe rain, and the water that fell on the surface, instead of stimulating to increased action, darkened the crust and nearly closed the vent.

We know so little of the laws of combined heat and pressure, that at present theory runs wild on the condition of the interior of our globe. One supposes a solid core surrounded by a melted coat, which in turn is covered by the solid crust of the earth; another supposes pockets or reservoirs of heated matter left in the solid crust of the cooling globe. All, however, are obliged to admit some source for the great streams of lava which are poured out upon the earth's surface. To explain all the phenomena of volcanoes it matters little what the interior of the earth may be, so long as we have a crust and a bed of melted rock below it. In the earliest ages of the globe, when the crust was thin, it was frequently broken as the earth cooled and contracted, owing to its being a poor conductor of heat, and contracting on its surface faster than it transmitted heat from beneath, and the escaping caloric found vent in numerous volcanoes over these fissures, precisely as on a smaller scale the surface of the lava in Kilauéa hardens and cracks, and allows the lava to boil up through the cracks. As the crust became thicker, the rate of cooling diminished, and the escaping heat needed fewer orifices, so that volcanoes became extinct. But the cooling process does not go on perfectly regularly; the crust is a better conductor in some places than in others, and this conductive power may vary from time to time. A high mountain with its rough surface abstracts more caloric from the earth by radiation than a smooth lake; continents more than the ocean. The balance is destroyed, and caloric must be transmitted through the earth to restore it. In what way the temperature of the earth's crust, at moderate depths, is kept so uniform we do not know; but we do know that the relative level of the land and sea is constantly changing, generally, as on the coast of Norway and the eastern coast of the United States, raising the land gradually at the rate of a few feet in a century, or in a similar way depressing the bed of the Pacific, the Baltic, and a part of the Indian Ocean. Or the change may be sudden, as during an earthquake.[1]

The bed of the ocean seems to be sinking and the land rising; but our knowledge of the earth's surface is yet too limited to inform us how extensively this is the case. The Hawaiian Islands are rising, and the atolls in the same ocean are sinking; and if we admit that the shallow bed of the Pacific, extending from the Hawaiian Islands to the China Sea, was once a continent, we have a case the reverse of those previously cited.

Wherever this change of level occurs over a tract of greater or less extent, there will be cracks of greater or less size along the boundary of this area; and here will the contracting crust force the lavas beneath, through to the surface. This fact was long since recognized by Humboldt, who says: "I am inclined to believe that islands and coasts are only richer in volcanoes, because the upheaval effected by internal elastic forces is accompanied by depression of the bed of the adjacent sea; so that an area of elevation borders on an area of subsidence, and at the limit between these areas great and profound clefts and fissures are occasioned."[2]

If the continents were not rising it would be difficult to see how they could maintain any height above the general surface of the globe, for meteoric influences constantly degrade and lower their peaks and slopes, and the material taken from them is constantly poured into the bed of the ocean, tending to fill that up, and reduce all to a common level.

The theory of a contracting crust, although not based on a sufficient knowledge of cosmic forces, yet seems to satisfy the known condition of volcanoes better than any other; and it also explains earthquakes which have been repeatedly shown to be unnecessary to eruptive action.

This theory, briefly expressed, is this. The earth's crust contracts unequally owing to its various composition, structure, and form, causing certain portions to fall below the general level, opening rents at the boundaries, and forcing up molten matter to the surface. The vibration of this gradual change of level, and consequent disruption of beds of rock, giving rise to earthquakes.

Mineral Products of the Hawaiian Volcanoes.

In the classification of the Hawaiian minerals I have followed the arrangement of Prof. Dana. The rocks, however, present some difficulties, since the metamorphic influences are both continual and considerable. The usual division of lavas into *basaltic* and *trachytic* is most unsatisfactory, since the lavas under consideration are mostly intermediate, of the *clinkstone* variety. If we attempt to draw a line between the recent and ancient, there are lavas yet hot which can hardly be distinguished from some that have been exposed to meteoric influences for centuries. Nor is the chemical composition sufficiently constant to serve as a basis of classification.

[1] The island of Tongatabu in the Friendly Group, during a recent earthquake, was depressed on the north-east side, so that the sea advanced on the land two miles, while the western coast rose several feet.

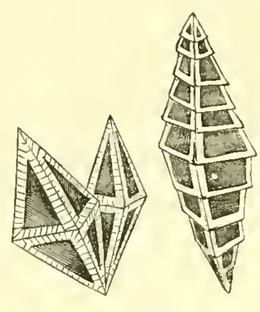
[2] Kosmos, iv. 415, Sabine's trans.

I have therefore placed first, the fresh lavas which reach the atmosphere in a liquid condition, a class varying in each crater, and even in consecutive eruptions of the same crater; next, the lavas acted upon by gases while still heated; lavas more or less decomposed by aqueous and acid vapors; lavas acted upon by the atmospheric agents simply; and finally lavas which reach the air through water, by which they are more or less comminuted and decomposed, forming tufas.

As the Hawaiian lavas are extremely liquid, the component parts have every opportunity for free motion, and from this perhaps results the homogeneity of most of the ejected matter. With the exception of chrysolite and augite no minerals have been found in the lavas which have not been formed, in all probability, since the matrix has cooled.

Native Sulphur.

This mineral is found principally on the outer walls of Kilauéa, and over the fumaroles in Púna which are in close connection with this crater. As the sulphur is first deposited in the crust of the decomposed lava, near the surface, it is usually in fine almost acicular crystals of great beauty. The heat varies from time to time, and the crystalline deposits are often melted by the high temperature (220° Fahr. observed), and form on cooling thin and irregular layers or veins which show an almost prismatic structure, breaking readily in planes at right angles to the surface of the layers. The color is usually pale lemon yellow, but occasionally the presence of selenium is indicated by a deep orange color. The crystals are seldom perfect, being usually formed of concentric coatings with cavernous faces. A remarkable specimen is represented in the figure of the actual size. It was found in Púna and drawn on the spot; it was so exceedingly brittle that it broke in fragments on removing it from the slab of lava under which it formed. The opposite ends of the vertical axis are not symmetrical, and while the successive layers commence at the upper pole and terminate abruptly at equal intervals as they approach the diagonal axes, the layers on the lower half of the crystal commence on the plane of the diagonal axes, and terminate as on the upper half, but in reversed order. This was by no means an unique specimen, many similar ones were observed.



Sulphur Crystals.

The whole amount of sulphur on the Hawaiian Islands is small, and it will perhaps never become an article of commerce, but the deposits are generally quite pure and easily reached. The absence of this mineral, so commonly considered a necessary concomitant of volcanoes, on the other islands, with the exception of the few traces on Háleakala, arises perhaps from the fact that sea-water does not intercept or commingle with the sulphurous fumes. The Sicilian deposits were probably due to the presence of the sea above the lower parts of Trinacria where the sulphur is mostly found. So in Spain, and at Husavik and Krisuvik in Iceland, and at the sulphur-beds of Japan.

Pyrites.

This is not found in any recent lava, but apparently arising from decomposition of the silicates containing a large proportion of ferruginous oxides, by aqueous action; as the globular or reniform nodules, the most common form, are usually found in wet places where the ancient lava has long been exposed to the water. So comparatively rare is this mineral, that natives have often brought me a carefully treasured fragment believing it gold, and eager to find more.

Common Salt.

This mineral is not common in the crater of Kilauéa, and there are no traces of it in the tufa cones, with the exception of Aliapaakaì where it is deposited in crusts and concretions every dry season, to be redissolved at every freshet. In former times this salt lake furnished a large supply of good salt, but for some years it has been wholly neglected. This is found on the upper walls as well as in the basin.

Sal ammoniac.

Generally this salt is much contaminated with iron in Kilauéa, where it is found in the caves, and just beneath the crust of the floor of the crater. B. Silliman analyzed a specimen obtained by the United States Exploring Expedition with the following result: —

NH^4Cl	$FeCl$	Fe_2O_3	$AlCl$	Insoluble and loss.	
65.53	12.14	8.10	13.00	1.23	= 100.

Specimens nearly pure were obtained in a crevice of a burning cone.

Hydrochloric Acid.

Taking Vesuvius as a model, it has been supposed that hydrochloric acid is a usual product of active volcanoes; it is, however, quite rare in Kilauéa, and I cannot find that it has been observed in the eruptions of Mauna Lòa. Very little is found even in combination.

Hæmatite.

Although the basaltic lava contains a large proportion of iron, enough to color the resulting soil bright red, no available deposits of iron ore have been found. A few fragments of hæmatite were found loose in the beds of streams on Kauaì, and near Nuuánu pali on Oáhu. They were much worn, and did not exhibit any external crystalline form. Perhaps an altered Limonite. A fine red powder was found on Oáhu which makes an excellent pigment.

Limonite.

On the edge of the lava flow of 1855 from Mauna Lòa, where it passed through a wooded land, rounded masses of this mineral were found from three to twelve inches in diameter and of the consistency of fresh putty, so that they could easily be cut with a knife, or moulded with the finger. On drying, these lumps crumbled and exhibited a fibrous structure. At Kaliiwàa on Oáhu, an ochre occurs of a finer texture. Both of these ochres form pigments of considerable body, little grit, and the color of burnt sienna. The impure varieties found near the sulphur banks, have been used in former times as paints, but are now wholly superseded by the better, imported ochres. It is highly probable that a more careful exploration, on the windward side of Oáhu, on Kauaì, and possibly in the northern districts of Hawaii, may result in the discovery of small beds of this important ore.

Sulphurous Acid.

The cloud of vapor which overhangs the active portion of Kilauéa, is mostly sulphurous acid. Boussingault found, in the volcano of Cumbal. hydrosulphuric acid only in the higher and cooler parts, where the temperature of the fissures did not exceed 185° Fahr., while in the hotter fissures sulphurous acid was abundant.[1] Humboldt saw, from the summit of Pichincha, that at a considerable depth in the crater blue flames moved about, and he distinctly recognized the smell of sulphurous acid.[2] The sulphur banks of Kilauéa have a temperature of 210° Fahr. just beneath the outer crust, while at a depth of several inches, near the steam cracks, the temperature rises as high as 220° Fahr.

This gas combining with hydrosulphuric acid, which is found in the cooler portions of the crater, especially when largely diluted with aqueous vapor, is decomposed, and furnishes the deposits of sulphur in the sulphur banks. Over the more intensely heated Halemáumau the hydrosulphuric acid is consumed on reaching the atmosphere, and this seems to be the source of most of the aqueous vapor in the cloud which overhangs the crater. The steam is in very small quantities, for the smoke is remarkably dry and consists almost wholly of sulphurous acid.

Sulphuric Acid.

In crevices in the sulphur banks small quantities of dilute sulphuric acid were observed, probably the result of the decomposition of hydrosulphuric acid. Many years ago Breislak observed that unless this gas was considerably heated when coming in contact with the atmosphere, no sulphur was deposited, but sulphuric acid was formed.[3]

Carbonic Acid.

Nowhere in the crater is carbonic acid evolved; and I have not seen proofs of its existence in a free state anywhere about the Hawaiian volcanoes. It is by no means a usual concomitant of volcanoes, and seems limited to those which, like Vesuvius, penetrate limestone strata of a former age.

Sassolin — Boracic Acid.

This was observed in minute quantities in only one fumarole, although looked for with care. It encrusted the decomposing lava, and was much mixed mechanically with sulphate of lime and with silica.

Quartz.

Fine crystals have been found in *cavities* of ancient blue basalt at Onomèa, Hawaii, which were from half an inch to an inch in length, quite symmetrical and without modifications, usually attached by the basal pyramid to the basaltic matrix. The cavities in which they were found were generally smooth within. Milky quartz is quite common on Molokaì and other islands, and occurs in irregular rounded masses, from one to eight inches in diameter; it is often colored superficially by oxide of iron. Chalcedony is found in botryoidal masses, and mamillary concretions, often of considerable beauty, on Kauaì, and has been formed by the solution of the silica in the lava by the soda, set free, perhaps, by atmospheric agency; and this soluble silicate of soda is again decomposed, depositing the silica in thin layers. The silica, separated from the basalt in the sulphur banks, forms a cement for the aluminous earths with which it seems mechanically united, and so far as I have observed, is not separated in these places in distinct masses. The quartz crystals found at Onomèa were undoubtedly formed after the lava cooled, as they were found within spherical cavities attached to one side, with perfectly sharp angles. The stratum of blue basalt was about twenty feet thick,

[1] *Annales de Chim. et de Phys*, t. lii. p. 5.
[2] *Ibid.*, t. xxvii. p. 129.
[3] Bischof, *Chem. Geol.*, vol. i. p. 330.

covered with four feet of earth and about a foot of good soil, the crystals being near the bottom of the bed which was cut away to form a roadway.[1] The most common form is milky quartz stained with oxides of iron, found on Molokaì and Kauaì. I have never seen this form from the other islands, although it doubtless occurs.

Augite.

Augite is the common constituent of all the recent Hawaiian lavas, but it is only in the tufa cones that crystals of any size occur. The variety termed Palagonite by Von Waltershausen is common at Leáhi, Kóko, and Aliapaakaì, where the rather rough crystals are imbedded in the tufa, and seem to be broken and worn. The Hawaiian specimens have not been analyzed, but the composition of this variety is so remarkably uniform that I quote the analyses of Von Waltershausen.

	$Si\,O_3$	$Al_2\,O_3$	$Fe_2\,O_3$	Ca O	Mg O	Na O	K O	H O	
Krisuvik	40.68	14.59	14.24	6.95	7.65	1.84	0.45	13.60	= 100
Heckla	40.75	8.42	17.99	8.64	4.54	0.62	0.44	18.60	= 100
Gallapagos	38.07	13.03	9.99	7.54	6.58	0.70	0.94	23.15	= 100
Val di Noto	40.86	10.07	20.54	4.46	3.28	3.99	1.10	15.70	= 100

Chrysolite.

This mineral is very common in most of the lavas that have issued low down the flanks of the mountains. On the summit no traces are found in the massive clinkstone which forms the crater walls. In the flow of 1840 from Kilauéa the a-a is full of it, and where the stream entered the sea the matrix was so pulverized that the chrysolite was set free and is now washed up in the clefts of the rocky shore as a green sand or gravel. The larger grains are amorphous, half an inch in diameter, while the smaller sand is used in mortar for fire-bricks. At Aliapaakaì fine spheroidal masses, sometimes four to six inches in diameter, are found, and in these the grains seem to be flattened against each other. I found chrysolite in some scoriæ on the top of Hualalaì, and in a lava of ancient date in Kilauéa. It is not uncommonly altered by the oxidation of the iron into a red and softer mineral. It is found changed to a red color in cellular basalt on Oáhu containing Thompsonite.

Garnet.

Only two specimens of garnet were seen, both at the summit of the cliff at Aliapaakaì. The crystals were dark red, a quarter of an inch in diameter, dodecahedrons, with the edges truncated by the planes of a tetragonal triakis-octahedron.

Biotite.

A few small tabular hexagonal crystals, nearly black, with a submetallic lustre, were found imbedded in the tufa at Aliapaakaì.

Labradorite.

It is not uncommon in the crater of Háleakala, also on Mauna Lòa, where it occurs in

[1] Quartz crystals, with perfect pyramidal faces at both ends of the crystal, were found in trachyte in the Andes of Bolivia, by Forbes. *Quart. Journ. Geol. Soc.*, xvii., pp. 26 and 29.

glossy colorless crystals. It is doubtless a component of many of the basalts. An analysis of a specimen from Máui by Schlieper gives —

SiO_3	Al_2O_3	Fe_2O_3	CaO	NaO	KO	MgO	
53.98	27.56	1.14	8.65	6.06	0.47	1.35	= 99.21.

Orthoclase — Feldspar.

Feldspar has not been found in separate crystals, but enters into the composition of the phonolites of the higher mountain regions, and the solid mountain core. The decomposition of feldspathic rocks by sulphurous vapors sets free the silica, and results in the recombination of the elements into various species. Clays are found on all the islands, especially on Oáhu and Máui, and in the district of Hána. On the latter island, much coarse pottery was manufactured some years ago. Bricks also have lately been made.

Prehnite.

It is found in the cavities of ancient basaltic rock on Oáhu, in pale green compact granular masses. Seldom found near the surface of the rock, so only seen when the rock is quarried for building purposes. Not common.

Thompsonite.

This mineral is found in lavas containing much olivine on Oáhu and Hawaii; it usually completely fills the cavities, forming an amygdaloid.

Natrolite.

Natrolite is found in the same rock as the last, and is usually of a gray color, vitreous lustre and radiating structure. I have never seen it *in situ*, but in fragmentary rocks the centre of radiation seems to be always on the same side of each cavity in the same specimen.

Scolecite.

A radiated crystalline mass, much resembling natrolite, gave the well-known blowpipe indication of scolecite, but was not further analyzed. Other zeolitic minerals will doubtless be found in the older lavas whenever the rocks are excavated to any extent. In many places I have been struck with the resemblance between some Hawaiian lava beds, and those in the Ghâts of Western India, where such rich deposits of apophyllite and other zeolites have been found, especially in the deep excavations at the Bore ghât. The so-called amygdaloid in this place is no older, apparently, than some of the cellular lavas on Oáhu, and is of the same nature.

Gypsum.

This is found beautifully crystallized in Kilauéa, both beneath the crust around the fumaroles and on the tube stalactites in the caves. Sometimes the long slender tubes pendant from the roof are completely covered with opaque white rhombic crystals thickly agglomerated, and at other times with long transparent acicular crystals often stellate. Both varieties are found in the same cave and even on the same tube, but always where both forms are so closely associated, the transparent crystals are at the end of the tube, and as this grows by successive deposits of silica and other soluble parts of the superincumbent rock, the opaque crystals form over and conceal the former. The temperature of the caves where the gypsum is deposited is not high, as will be seen in the description of the stalactitic formations farther on.

No beds of gypsum have been found in the upraised coral reef, and there does not seem to have been any submarine emission of sulphur vapors to produce this deposit.

Specimens of the gypsum-coated tubes of both varieties have been deposited in the Museum of the Society.

Cyanosite.

An impure sulphate of copper is sometimes, though rarely, found in the sulphur beds of Kilauéa. An analysis, given in the Geological Report of the United States Exploring Expedition, is as follows: —

$HO\ SO_3$	Na O	Cu O	Al+Fe	Mn	K Cl	$Si\ O_3$ (insol.)	Si and loss.	
37.97	16.80	10.80	5.0	4.0	trace	21.00	4.43	= 100.00

Soda Alum — Solfatarite.

A strongly ferruginous soda alum is found in the smoking cones (fumaroles) in Kilauéa.

Halotrichite.

As the fibrous silky mass of the alum often contains little soda, it seems to run into halotrichite. The free sulphuric acid in this mineral is often quite perceptible, and wholly destroys the paper in which it is placed for a few days.

Copperas.

It is found in the sulphur bank on the southern edge of Kilauéa; it is quite impure, and from its solubility is usually dissolved as soon as formed, and is absorbed into the porous earth resulting from the decomposition of the lava rock.

Glauber Salt.

At Kailùa, on the western shores of Hawaii, this mineral was abundant twenty years since, forming in a cavern on the shore by the action of hot sulphurous gases on sea-water. These gases have ceased to flow, and the springs are no longer hot. I did not visit the place, but was told that no sulphate of soda was now found there. In Kilauéa it is not uncommon as a deposit on the under-surface of lava crusts, and contains a little sulphate of lime and sulphate of iron.

Nitre.

Found in small quantities in Kilauéa on a ledge in a cave, in delicate acicular crystals. The rock on which it was found was too porous to hold water, and the crystals must have formed from a vaporous solution, or grown from the saturated rock.

Calcite.

The chief deposits of carbonate of lime on the Hawaiian Islands are the extensive coral beds. These are often very compact and solid, often baked by lava-streams to a compact limestone, and ringing when struck. Where the lava has broken through the raised coral reef, as in the shore craters of Oáhu, the particles of coral are carried up with the tufa, and may be found imbedded in an almost unaltered condition. It is usually, however, acted upon by heat and sulphurous gases forming gypsum and aragonite. As a white incrustation it is exceedingly common on all the tufa cones on the ancient reef, and sometimes is of quality and quantity to be used as chalk, especially the deposits at Leáhi and Laelóa. In the caves at Haéna, on Kauaì, the roof is in many places covered with a thick incrustation of agaric mineral, and specimens were obtained several inches thick. I am inclined to refer to calcite the insoluble scum which was mentioned as occurring on the water in the second cave. It was here that the incrustation formed extensively, and the unevaporated water which had percolated from above dropped constantly from the roof. The incrustations are mamillary and botryoidal, and of a reddish-yellow tinge, often cellular in structure.

The coral rock is burned for quicklime, which is not, however, considered of so good quality as that made from other limestone. The calcareous matter, however, cements together fine volcanic sand, forming the coral-shaped masses of sandstone at Kolòa on Kauaì, the beach sandstone of Hanaleì and elsewhere, and the curious sand tubes of the Isthmus of Máui. It also cements together the black gravel near Honolulu, forming cylindrical and rounded masses, often resembling fossil bones.

Arragonite.

Sometimes found mixed largely with calcite incrusting caves. The crystals are small and inconspicuous, and the corolloidal form is more common.

Hawaiian Rocks.

Fresh Lava.

The lava spattered out of the pools cools rapidly in the air, and presents when cold a glossy black exterior usually quite smooth, somewhat resembling coal tar, while the interior of the drops is sometimes hollow, and oftener filled with a cellular mass perfectly vitreous. The lava drops are indeed miniature volcanic bombs. Although as they are seldom projected to any considerable height the contained gas has no opportunity to burst the solidified shell in a rarer atmosphere; and as the lava is still red-hot when it strikes the ground, provided the pieces are more than half an inch in diameter, the drops flatten and lose completely the spheroidal shape they assumed during projection. The drops are exceedingly brittle, and split readily with the least jar, presenting a conchoidal fracture. The lava of which they are composed is so poor a conductor of heat that a fragment, a quarter of an inch thick, may be held in the hand within an inch of the red-hot extremity.

Pélé's Hair.

The filamentous lava formed by the adhesion of the drops to each other, or to the surface of the pool, varies in color and fineness. During the eruptions on the slopes of Mauna Lòa, when the lava fountains often play to a great height, the wind spins out Pélé's hair in clear green or yellow threads, sometimes three feet in length and rather coarse. In Kilauéa, the threads are finer,[1] and although clear and transparent when first formed, are soon corroded on the surface by the sulphurous vapors so abundant there. This decomposition is rapid, and on the leeward banks a strong cement is formed with the dissolved silica.

Various analyses have been made of this curious product, and as the drops are of essen-

[1] I have seen a bird's nest wholly made of this Pélé's hair, beautifully interwoven. When found in the crater, it contained two eggs. It is now in the possession of Mr. D. R. Hitchcock of Hilo.

tially the same material, the results of examinations of both these forms may be placed side by side.

	SiO_3	Al_2O_3	FeO	Fe_2O_3	MnO_2	CaO	MgO	NaO	KO	HO			
I.	49.0	13.0	15.0	——	7.8	8.9	0.4	4.5	2.3	——	=	100.9	C. T. Jackson.[1]
II.	49.2	7.8	——	13.7	13.0	8.4	5.1	1.8	trace	0.5	=	99.5	J. C. Jackson.
III.	51.19	——	30.26	——	——	——	18.16	——	——	——	=	99.61	B. Silliman, Jr.
IV.	39.74	10.55	22.29	——	——	2.74	2.40	21.62	——	.33	=	99.67	" "
V.	50.00	6.16	28.72	——	——	7.40	——	2.00	6.00	——	=	100.28	J. Peabody.
VI.	50.67	——	33.62	——	——	3.66	1.13	10.52	——	——	=	99.60	B. Silliman, Jr.
VII.	51.93	14.07	16.91	——	——	6.20	1.73	6.31	——	——	=	97.15	" "

I. Lava drops. Color dark bottle-green; very frangible, like unannealed glass. Sp. gr. 2.7; from Halemáumau. II. Pélé's hair from Kilauéa in 1864; both protoxide and peroxide of iron were present, but owing to the presence of oxide of manganese the proportions could not be determined. III. Pélé's hair from Kilauéa in 1840 (United States Exploring Expedition). IV. Pélé's hair, ditto. V. Pélé's hair light colored, ditto. VI. Vitreous lava from Kilauéa; Sp. gr. 2.91. VII. Scoria from Kilauéa 1840; Sp. gr. 2.505. Of the last five the solubilities in hydrochloric acid were as follows: —

	Soluble in hydrochloric acid.	Insoluble.
III.	49.51	50.49
IV.	48.80	51.20
V.	——	——
VI.	42.50	57.50
VII.	45.84	54.16

Crust.

The fresh crust from the surface overflow of the pools often looks quite firm on the surface, while within it presents a series of small cells surrounding larger, all with the walls of a brilliant metallic lustre. Its composition closely approaches that of Pélé's hair. The lava that breaks out of the cones in Kilauéa is less porous than this scum, but is still quite cellular. It is viscid, and where it runs over light scoriæ does not sink into the porous mass, but flows above, bending slightly, where unsupported, between the fragments. Often a fractured surface is brilliantly iridescent. The bubbles or air-cells are generally, but not always, elongated in the direction of the flow. Usually the fresh lava exhibits chrysolite in exceedingly small particles, and so red as to mislead at first in regard to its true nature. Where a large quantity of lava escapes at once, the cooled crust is quite distinct from the cellular portion under it, and is quite compact, vitreous, and easily separable from the rest of the mass. As the small streams cool almost equally above and below, the melted matter solidifies in a cylindrical form which twists if one side cools faster than the other, and produces the rope-like masses so common on the outskirts of lava flows. If the supply is very abundant, the cooling goes on principally at the upper surface, and broad sheets of a sort of pahoehoe are formed. What is most curious, while the general mass of a lava flow — I am now speaking of the comparatively insignificant flows from the pools in the crater — is of a tolerably compact stony nature, a thin layer of very cellular lava separates it from the compact vitreous crust. It is so often declared that the surface of lava is porous and spongy from the escaping gases, that I have been surprised to find that this is not the case. The surface, although covered with glassy scales, perfectly flat and by no means bubbles, is more impervious to gases than is the lower stony mass. The lava as it flows out is not in an effervescent state; it is simply melted, not boiling rock, and evidently

[1] This, and other analyses, were kindly made for me by Dr. C. T. Jackson and his son Mr. J. C. Jackson.

is not brought to the surface by the rise and expansion of inflating vapors. That vapors accompany it is perfectly true, but the molten mass is often drawn from a cone some yards below the surface of the liquid which emits gases, and the product is smooth and glassy; not a bubble disturbs its rapidly hardening surface, and often no vapor accompanies its egress.

That the lava is not much above the melting point on the surface of the Halemáumau and other pools in Kilauéa, is evident from the great rapidity with which it becomes granular. Where the substance is drawn out by gravity the granules are very distinct, even when the lava was liquid enough to form pendants a foot long. Several stalactites formed from melted lava exhibit this structure admirably. The lava is melted as the Rowley rag is melted in the furnaces of the Messrs. Chance, and is not a simple solution in some vehicle. Dolomieu, in speaking of volcanic fire, says: "Il produit la fluidité par une espèce de dissolution, par une simple dilatation qui permet aux parties de glisser les unes sur les autres, et peut-être encore par le concours d'une autre matière *qui sert de véhicule à la fluidité.*"[1] Elsewhere he supposes this vehicle to be sulphur, a supposition not more improbable, judging from Kilauéa alone, than the theory of Mr. Scrope, that water is the interstitial fluid which imparts mobility.[2] The fusion is perfect as seen in the Pélé's hair, and when the lavas granulate they do so without any disengagement of vapor. I have seen the streams or rills of lava moving with such entire freedom from any thing like smoke, that had I not been watching, they might have passed near me unnoticed. Wherever the melted rock passes over combustible matter, or through swamps, the vapor generated is sufficient to convert the surface and mass also into a porous rock. It must not be inferred that gases never inflate the lava in the crater. Much of the surface overflow is, as has been said, a spongy scum, but it is only the surface overflow that is so porous, and if water is necessary — if vapors are necessary to the elevation of the matter — these gases must be in a state of greater tension lower down in the column, and ought to froth out when an outlet is provided; and we should have, with the pressure of a column of lava three thousand feet in height, a result similar to that produced by the sudden expansion of liquid carbonic acid, and a black or green snow would surround the vent. Something like this seems to occur, but in quantities wholly inadequate to the agency supposed. Around the orifice of 1859 on Mauna Lòa are several cartloads of a very light porous substance, called by the natives *límu* or moss. It is dark green and smooth on the surface of the irregularly rounded nodules, while the interior is light green. The same límu forms large beds on the leeward bank of Kilauéa, and there its origin is explained; it is simply the scum from the Halemáumau blown away by the wind, not by liberated gases, and its formation is going on with that of Pélé's hair.

Pumice.

The structure of the fresh lava is not easy to understand, some parts of the same stream having a clear ring when struck, others being dead and flat. The mode of granulation certainly has much to do with the phonetic qualities of lava, as the a-a or simple granules sound quite differently in different places, although of the same composition and appearance. The a-a of Kilauéa contains but little olivine, and that in small grains; this is true also of that formed on the slopes of Mauna Lòa from the summit discharges; but the flow of 1840 from Kilauéa at a considerable depth, produced an a-a full of large grains of this mineral. The specific gravity of a specimen from Kilauéa is 2.47. The formation of this rough and curious product has already been discussed.

A-a.

[1] *Les Isles Ponces*, 1788, avant propos, p. 8.
[2] Scrope *on Volcanos*, p. 116.

Rapilli.

When the melted lava is thrown into water, the black gravel called lapillo or rapilli results, and the iron which it contains as peroxide becomes magnetic. From the loose form of this gravel it is readily transported by water, and is generally spread out in horizontal layers near the shore, often covered, as near Honolulu, with other alluvial deposits.

Electric Lava.

In one blow-hole, Mr. Rexford Hitchcock found some very curious forms of lava which, for want of a better name, may be called as in the margin, for I conceive them to have been formed by the action of electric currents on a plastic mass containing much iron. The masses are of considerable specific gravity (2.857), and the surface is arranged precisely as the iron filings place themselves around the poles of a magnet. Similar specimens were found in Vesuvius, and are in the Museum of the Society; but in Kilauéa only this one locality has been discovered.

Sand.

Only in the eruption of 1789 has volcanic sand or ash been ejected, and this is simply irregular, angular, and rounded grains of the ordinary lava of the pools, comminuted perhaps by the explosive violence of the eruption. It is not so fine as the ash of Vesuvius, and although it is apparently but little acted upon by meteoric influences, rounded particles of calcareous matter are found in it in considerable quantities.

Heated Lava acted upon by Gases.

The immediate result of gases, usually sulphurous vapors, is to change the external color of the lava, so that as it cools it assumes various shades of brown, red, blue, yellow, and often a metallic hue, so as to resemble brass. The color imparted in this way is quite superficial, and the action of the gas is but momentary, but the results are often very beautiful. The heat of gas-jets seems to remelt the angles of the consolidated lava. Much more important, however, is the

Decomposition by Aqueous or Acid Vapors.

Tubes.

A formation which always excites the curiosity of visitors to Kilauéa, is found in many of the caves in the floor of the crater which have been undisturbed for several years. At the first glance the tubes which hang from the roof, and the curiously formed droppings beneath these, seem to be of igneous origin, or droppings of melted lava from the roof. An examination *in situ* shows that this was not the case. The roof of these caves is about two feet thick and generally unbroken; the stalactites do not occur under cracks, and indeed there is often no fresh lava over the surface. The formative process may be clearly seen, as the tubes grow from day to day; and I have caught the steel gray deposit in the drops on the end of the tubes upon my finger and watched its solidification. Usually the tubes are straight cylinders, from one to three eighths of an inch in diameter, and sometimes more than two feet long. The bore is almost never continuous, and while externally they are smooth, within, a mass of stony cells of considerable size is presented. As long as these tubes grow downward in the quiet upper region of the cave they hang perpendicularly, but when they reach farther down the currents of air and steam blow the deposits to one side and the tube becomes distorted; it may even return on itself. The drip on the bottom forms much thicker and more irregular stalagmites[1]

[1] A very beautiful stalagmite of shining black obsidian from Iceland, formed with surprising regularity, is in the cabinet of Harvard College.

as will be seen from the figure, which represents three actual forms, not occurring, however, in the same cave. Specimens have been found which exceed eight inches in diameter, and these are usually low and flat-topped. The more slender ones sometimes rise to a height of two feet; and so rapidly is the silica deposited, that they seldom increase in diameter, but are true acrogens, none of the suspended silica running down the sides. In one cave the growth of the stalactites was at about the rate of an inch a week, but owing to the varying amount of water or steam the production is quite irregular. They are often coated with beautiful white crystals of gypsum, sometimes tipped with needle-like transparent crystals of the same mineral, where the cave is high. The natives collect them with the upper open joint of a long bambu.


Fig. 48.

The process of formation is this: the water from the frequent rains, and the condensing steam, act upon the soluble portion of the superincumbent rock, carrying along the silica and lime to be deposited in the form of tubes and their encrusting gypsum, and the resulting stone is quite anhydrous, as will be seen from the following analysis of specimens not coated with gypsum.[1]

$Si O_3$	$Al_2 O_3$	$Fe_2 O_3$	Mn O	Ca O	Mg O	Na O	K O	
51.9	13.4	15.5	0.8	9.6	4.8	3.0	1.1	= 100.1.

Specific gravity, 2.9. The temperature of the caves is usually from 80°–95° Fahr.

Other specimens, examined by Prof. Dana, had a hardness of 5–5.25, and a specific gravity of 1.656.[2]

The imitative forms arising from the evaporation of the siliceous solutions in the caves, are often quite curious, some resembling bunches of dried raisins, from a partial collapse of the encrusting bubble. The structure of all is stony and very cellular.

Acid vapors exercise a more extensive influence, but only in combination with steam. The surface of the black lava is first colored white or yellow, and the decomposition extends throughout the mass, rendering it after a while friable, and if the aqueous vapor is in excess, reducing it to an earth which is often again consolidated by the dissolved silica. A portion of spattered lava exposed to this action may be colored quite differently from the rest of the mass. Thus yellow or orange drops appear on a red ground, brown on a purple, and so on in great variety.

In the sulphur banks changes are going on quite rapidly, and the soil which results from the decomposition of the ancient lava of the outer walls of Kilauéa does not differ in appearance from that formed in the crater from the fresh black vitreous lava. The stony lava is always first decomposed, and the vitreous crust resists longest. In Púna I have raised large slabs of the crust which were nearly entire, while the stony stream underneath was reduced to a red earth for more than eighteen inches deep. Wherever cracks permit the passage of gases through the crust the interior is attacked. Most of the salts are deposited in these cracks and beneath the crust.

Clays are formed both by acid vapors and by simple meteoric influence. Those near

[1] Analyzed by Mr. John C. Jackson in the laboratory of Dr. C. T. Jackson.

[2] *Geology of the United States Exploring Expedition*, p. 201.

Kilauéa result from the former agency, and are usually bright red, tenacious, and gritty. The undecomposed lava contains more silica than is required to form clay with the alumina, and consequently clays are not always produced. At the sulphur banks a curious alternation of earths containing more or less silica has been observed, the more clayey containing twigs or other vegetable matter from the cliffs above, in a more or less fossil state, while the siliceous layers are thin and comparatively free from foreign substance.

Clays.

Decomposition by Meteoric influences.

Under this head we may range all the ancient lavas, and thus almost the entire mass of the Hawaiian Islands. I have already pointed out that the lava rock in the centre of the volcanic mountains is by no means the oldest; like granitic veins penetrating sedimentary strata its actual formation may have been long subsequent to the surface overflows which have formed the innumerable coatings of the dome. Wherever this central mass is visible, as in the deep valleys, it exhibits an amorphous, compact structure, gray or dark blue in color, and of considerable specific gravity. The composition is slightly different on the different islands, Háleakala containing a rock of lighter color and less specific gravity than Konahuanùi. I have never seen in either any cells which would permit the formation of zeolites.

Clinkstone.

The clinkstone beds on the summit of Maunas Lòa and Kéa are of two kinds, differing chiefly in color, one being gray, the other pale red or light brown. A partial analysis by Mr. J. C. Jackson gave: —

$Si O_3$	$Fe O + Fe_2 O_3$	$Al_2 O_3$	$Ca O + Mg O + Na O$	
52.0	25.2	20.6	2.2	= 100.0 Sp. gr. 2.91.

This is a very tough compact rock, chips with a conchoidal fracture, and is used for adzes. In ancient times, the only implements for cutting wood and shaping canoes were made from the rock of Hawaii, which was considered better for the purpose than any other. The composition of most of the summit lavas is trachytic. They take a good polish, and have the characteristic ring of phonolites. Olivine is quite rare, and I have never seen a single specimen from these compact rocks. The phonolites, like the other lavas, are in beds and much fissured. Both Kéa and Lòa are capped with this rock, mingled with the ordinary trachydolerite of Abich, which is the only stone on the other mountains.

Graystone.

The ordinary rock of the walls of the craters, both on Hawaii and on the other islands, is a compact heavy graystone, not cellular to any extent, and containing much olivine, usually of a pale yellow color. A mass in Kilauéa, evidently from the outer walls, has a specific gravity of 2.2. The summit of Háleakala, and consequently the walls of the crater, are of a vesicular trachydolerite, light brown on the surface where acted upon by the weather, but brownish black within. Fracture conchoidal and splintery. Specific gravity, 2.7. Much of this rock has in spots a structure similar to that of highly fermented dough — coalescing bubbles with intervening bundles of fibres. A specimen of stony lava procured by the Exploring Expedition gave —

$Si O_3$	$Fe O$	$Mg O$	$Na O$	
59.80	31.33	1.71	4.83	= 97.67 B. Silliman, Jr.

Specific gravity, 2.93. Soluble in Hydrochloric acid, 24.55; insoluble, 75.45.

Although the trachytes are often columnar, it is in the basaltic varieties that this structure is most beautifully shown. In many of the deep flows of lava from Kéa and Lòa, especially in the valley of the Wailuku, the columns are very perfect. So on Kauai near Huleia and in the Hanapépé valley. The dykes so common all over the group are usually of basalt, and the structure is generally prismatic, the prisms often separated by a thin calcareous film. Basalt.

Lavas which have been ejected through Water.

On all the islands there are found shore craters, and those on Oáhu have attained considerable size. The tufa of which they are principally composed is simply comminuted lava, cemented together by ferruginous or calcareous cement. The stone thus formed is tolerably firm and compact. It is in layers varying in thickness from half an inch to a foot. Where the eruption has taken place through the coral reef, the limestone thus mingled with the ash or mud is gradually decomposed, and fills the cracks with calcareous deposits. Sometimes this is so abundant as to whiten the whole surface of the rock. In a climate where frosts prevail, the loose porous tufa could not long hold together; and even in the tropics the rains fast reduce the hardest to soil. Sometimes the grain is coarse and much mottled with lime, while at the same place other layers may be fine and homogeneous throughout. In the tufa of Kóko small crystals of augite are seen, and also what closely resembles these, particles of obsidian. At Aliapaakai, these and garnets, mica and chrysolite, have been found, the latter abundantly in the tufa. Tufa.

Soils.

All the soil about Honolulu and Waikiki is simply tufa debris, and it does not differ essentially from that resulting from the decomposition of other lava. It is often bright red, like the original tufa. We have spoken of the clay soils, but they are not common; the usual earth is light, requiring constant irrigation to render it fertile. In the valleys and on the windward slopes of the mountains the rains are abundant; but where these fail all is dry and sterile; yet the soil is equally good, covering itself with verdure during the rainy season, although dry and brown all the rest of the year, and yielding good crops of cane, bananas, and cotton whenever artificially irrigated. The vegetable acids produce a rich black soil in the forest.

It will be seen that the lavas contain but little potassa, no titanium, so far as analyzed, and a large amount of iron oxides. The different varieties run into each other, and a complete chain may readily be formed from the clinkstone of Mokuawéowéo to the basaltic dykes of Hanapépé.

EXPLANATION OF THE PLATES.

Plate XI. Kauaì, Niihau, Kaúla, and Lehŭa.

This Map has been constructed from several manuscript maps kindly furnished by residents. As no general survey has ever been made, either of Kauaì or any other island in the group, it is not as accurate as could be desired, but is believed to be an improvement upon any yet published. The island of Niihau has been surveyed by Mr. G. N. Wilcox of Kauaì.

Plate XII. Óahu and the Hawaiian Group.

The Map of Oahu is drawn mainly from that given by Prof. Dana in the "Geology of the Exploring Expedition." The exact position of many of the valleys is as yet undetermined, and it has been necessary to merely indicate their general form and relation to each other. For the same reason the dotted line which represents the fringing reef denotes the position and general extent rather than the exact topography of the coral formation.

The Map of the whole group shows both the relative position of the various islands and action of the volcanic vents. Where these have clustered around a single point, as on Hawaii and Máui, a circle represents the position; where the line of eruption is elongated, as on Oáhu, an elliptical figure is used for the same purpose. The radiating lines serve to connect with these centres the various lateral cones which stud the great domes in determinate lines to the very shores, or even extend into the sea, as in the crater of Molokìni. So far as is known, all the lateral cones will fall into the lines represented, and it will be seen at once that they are remarkably parallel to four directing lines. The centre on the western part of Kauaì has been divided, to show the relation of Niihau as previously suggested. The same has been done with Lanai and Kahooláwe, although this is perhaps unwarranted.

Plate XIII. The Máui Group.

West Máui has been drawn chiefly from a manuscript Map by Mr. Horace Mann, and represents fairly the relative positions of the valleys.

Plate XIV. Hawaii.

One of the original features of this Map is the lava flows. Those along the coast have been represented from actual observation, and are only those whose aspect is still perfectly fresh and distinct; farther up the slope they are lost in the dense forest, and although they proceed from near the summit in almost every case, their upper course has never been traced. Mauna Kohála has been represented nearly in its true position, and Kilauéa has been recognized as an independent mountain. The region in the district of Hilo south of Laupahòehoe is not represented in its true character, as it would be difficult to even indicate on so small a scale the extraordinary nature of the intersecting ravines. The streams show the position of the largest, but as there are more than fifty large streams in a distance of thirty miles less than half are shown.

Plate XV. The Crater of Kilauéa.

This plan has been constructed from a careful survey by the author. Starting from the house at the north-east bank the circumference was chained, making the distance between the twenty stations on the wall of the crater 8.6865 miles. From each station bearings were taken with a large theodolite made expressly for the purpose. The summit of the Cathedral in the crater was made a central point to determine the relative height of the banks. The side crater, Poli-o-Keàwe, was not measured. Many of the cracks in the walls of the principal crater are not figured, and other details are omitted. A section across the southern end from A to B will give a fair idea of the elevation of the bottom towards the centre.

At each station the magnetic meridian was compared with the true meridian, obtained by careful observations of the pole star at its east and west elongation and the remarkable variation observed in the neighborhood of the northern pools has been noted on the plan. As the author was unassisted, save by a few kanakas who knew nothing whatever of surveying, he was unable to make the numerous measurements necessary to the construction of a relief model, but so far as the plan goes it is believed to be accurate.

The sketch of the Exploring Expedition Survey shows the Black Ledge, and with the plan by Lieutenant Malden, who accompanied Lord Byron in 1825, will indicate the constant changes taking place in the topography of Kilauéa. Neither of these plans, however, were measured with sufficient detail to serve as standards of comparison except in a general way.

The explanation of the numerals on Lieutenant Malden's plan, is as follows: —

1. Crater in action visited by Lord Byron.
2. Sulphur crater.
3. Crater that broke out on the 29th of June.
4. A cone very active all the night of the 29th.
5. Largest crater, always emitting fire and smoke.
6. Deep fissure in the lava.
7. From this point it was 932 feet to the Black Ledge.
8. Black Ledge 400 feet from the bottom of the crater.
9. Lord Byron's encampment.
10. A deep wooded crater.
11. Steam cracks.
12. A descent of twenty feet.

On the northern bank there was a constant smoke from the sulphur banks, and the western end of the crater was quite hidden by the thick vapors. Poli-o-Keàwe was "thickly covered with green underwood;" the descent on to the neck between this and Kilauéa was one hundred and fifty feet.

In 1846 a sketch map was made of Kilauéa, and on this the Black Ledge was estimated at 650 feet below the highest bank. The whole interior was elevated from one hundred to one hundred and fifty feet above the Black Ledge; rough and broken, sloping towards the north. Halemáumau was some twenty feet above this plain. The lava cataract of 1832 was estimated at three hundred feet in height. The walls of Poli-o-Keàwe were four to five hundred feet in height, and at the bottom was once a lake of lava thirty to fifty feet deep. Now the crust has fallen in and is marked with tree holes; it was from the outbreak of 1832. The variation near the house was 8° W. Steam issued from the south-west bank near the spot marked on the large plan "Beds of Basaltic Pumice."

Levelling revealed the curious fact that the surface of the various pools of melted lava was of different heights. Halemáumau presented a surface sixty feet above the Lakes of 1864, and fifty feet above those of 1865. Even the two pools of 1864 were not at the same level, but two or three feet different. With the great pressure lava must exert, and the apparently free communication between the several vents, it is difficult to understand this, unless the viscidity of the lava is greater at a considerable depth than on the surface. All the pools are above the base of the outer walls.

EXPLANATION OF THE WOODCUTS.

[From Drawings and Photographs by the Author, unless otherwise specified. Engraved on wood by R. B. Dyer, except numbers 37 and 38.]

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INDEX AND VOCABULARY.

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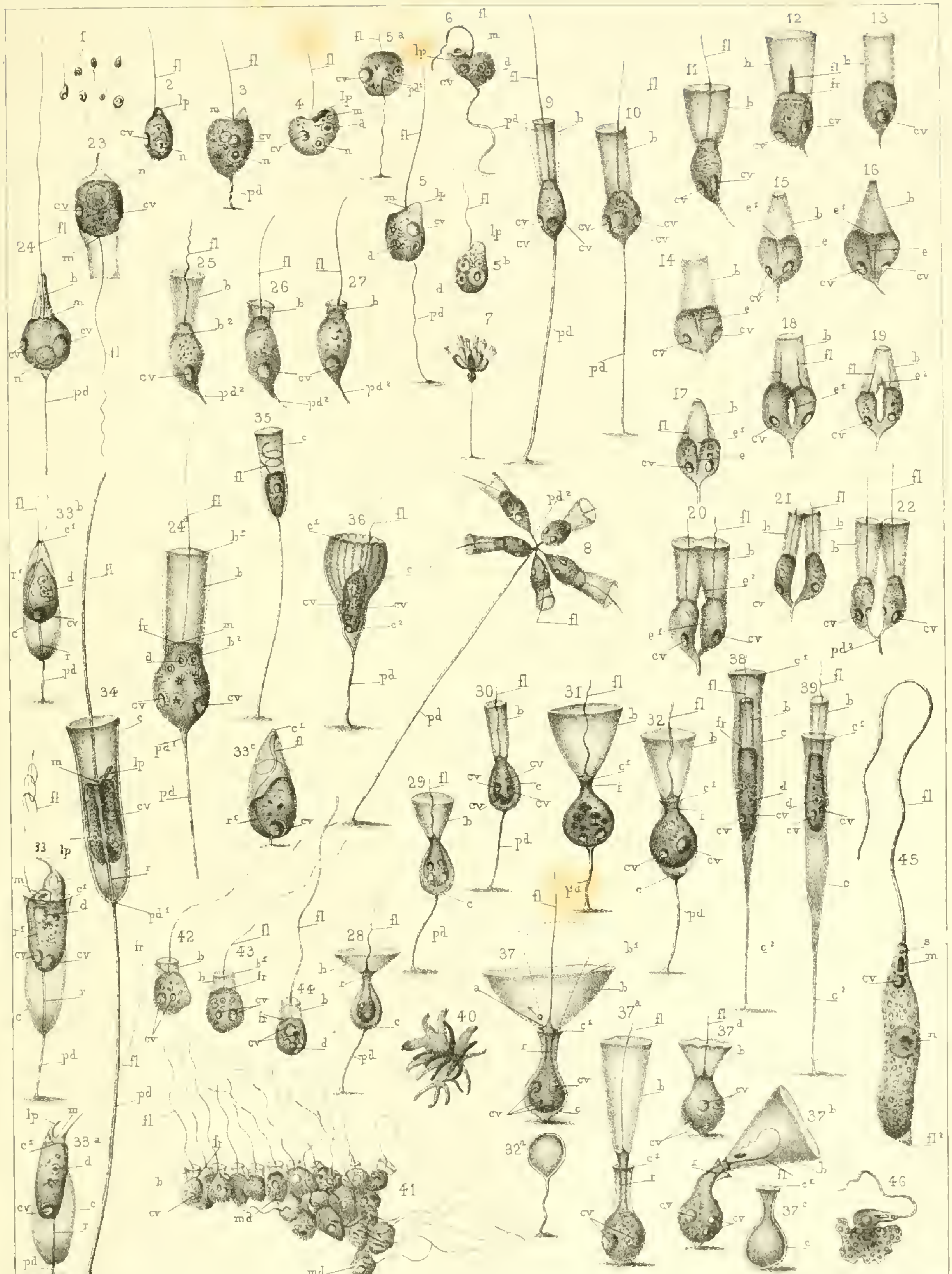

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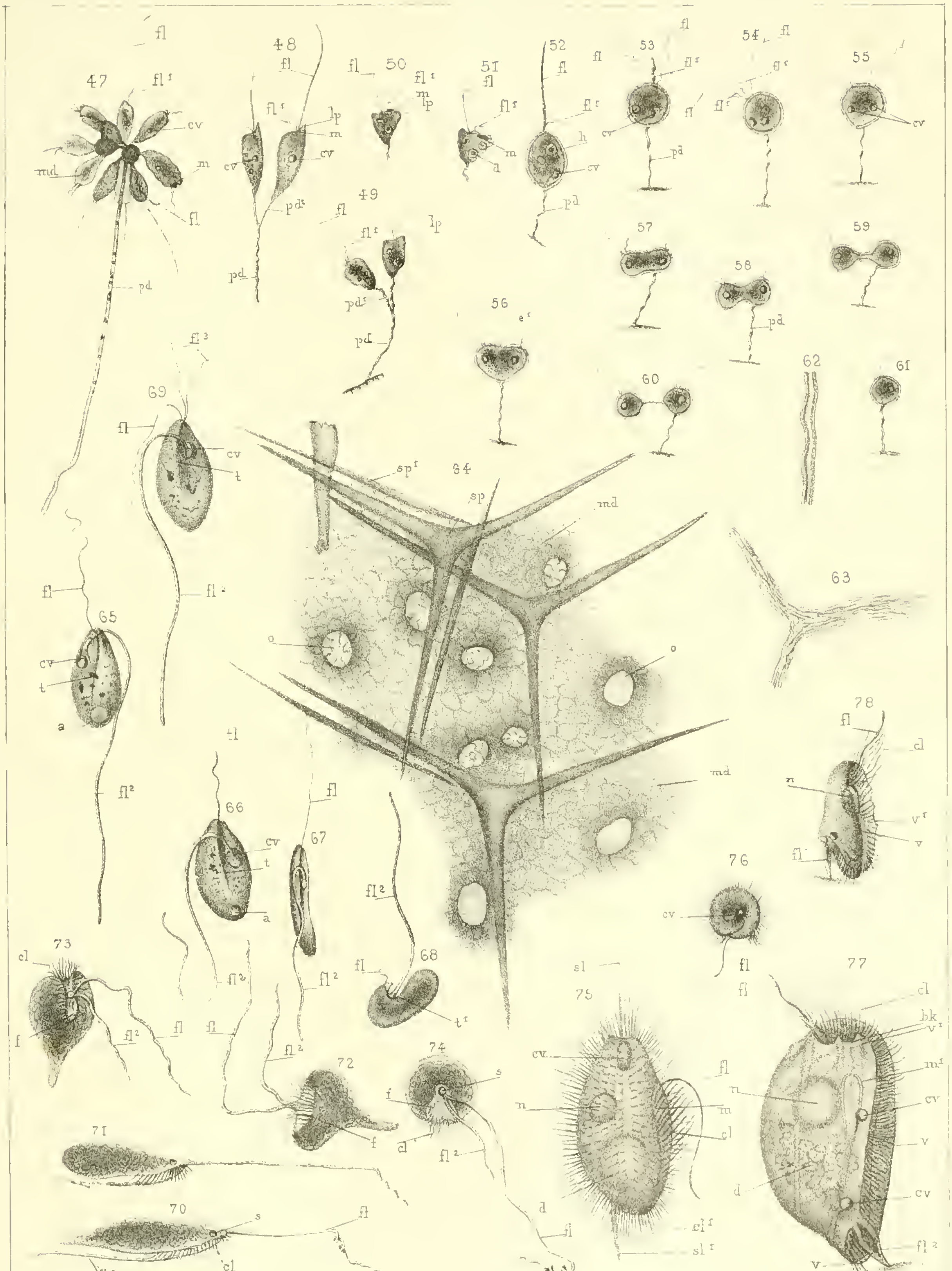

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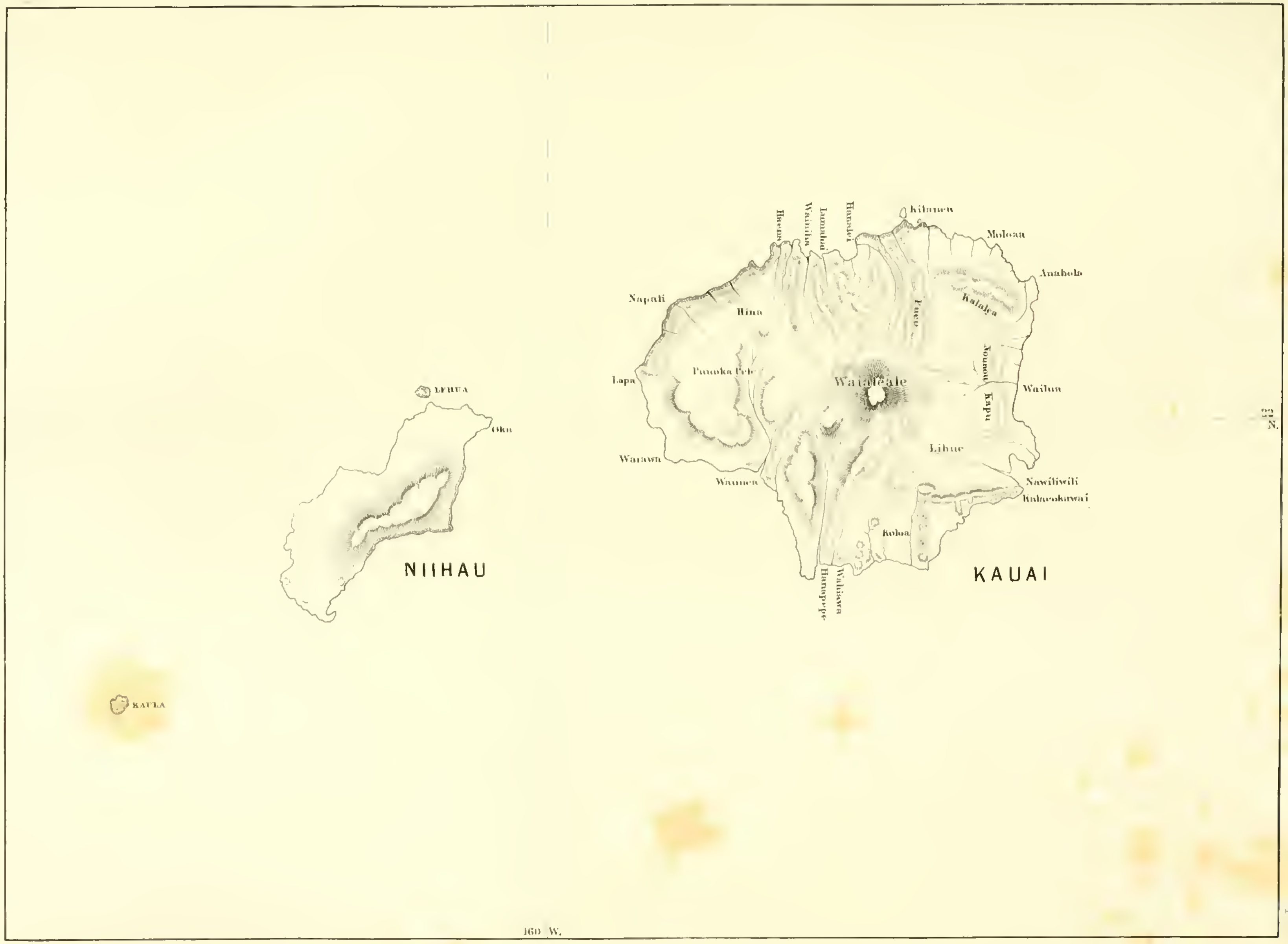
KAUAI
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Moloaa
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Kalalea
Pueo
Nounou
Kapu
Wailua
Waialeale
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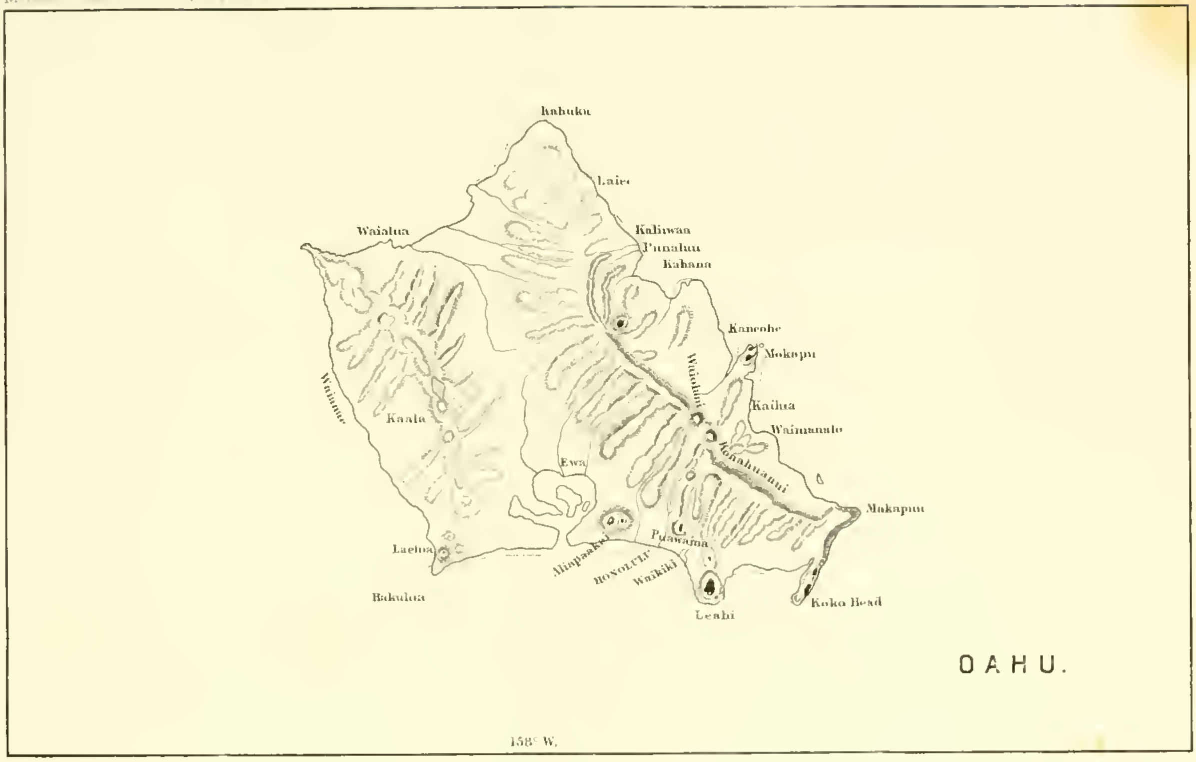
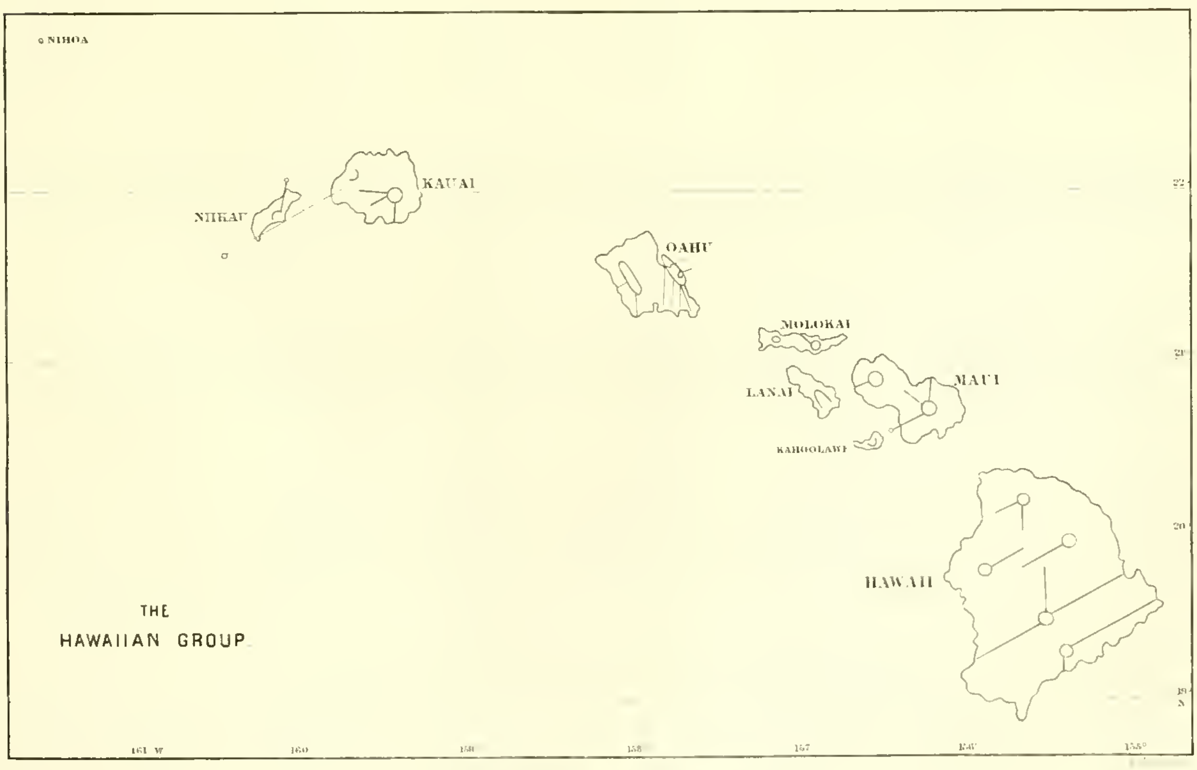
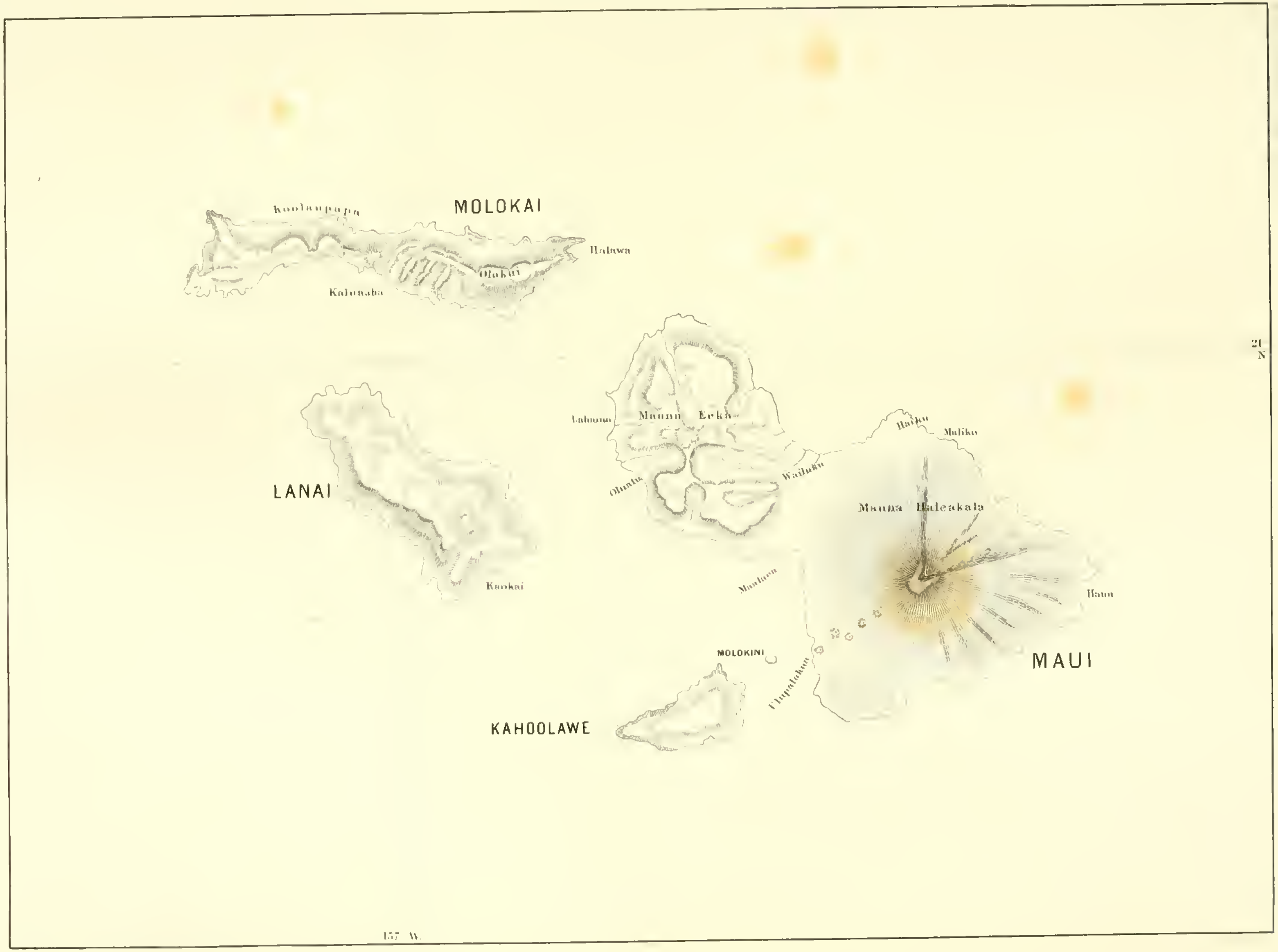
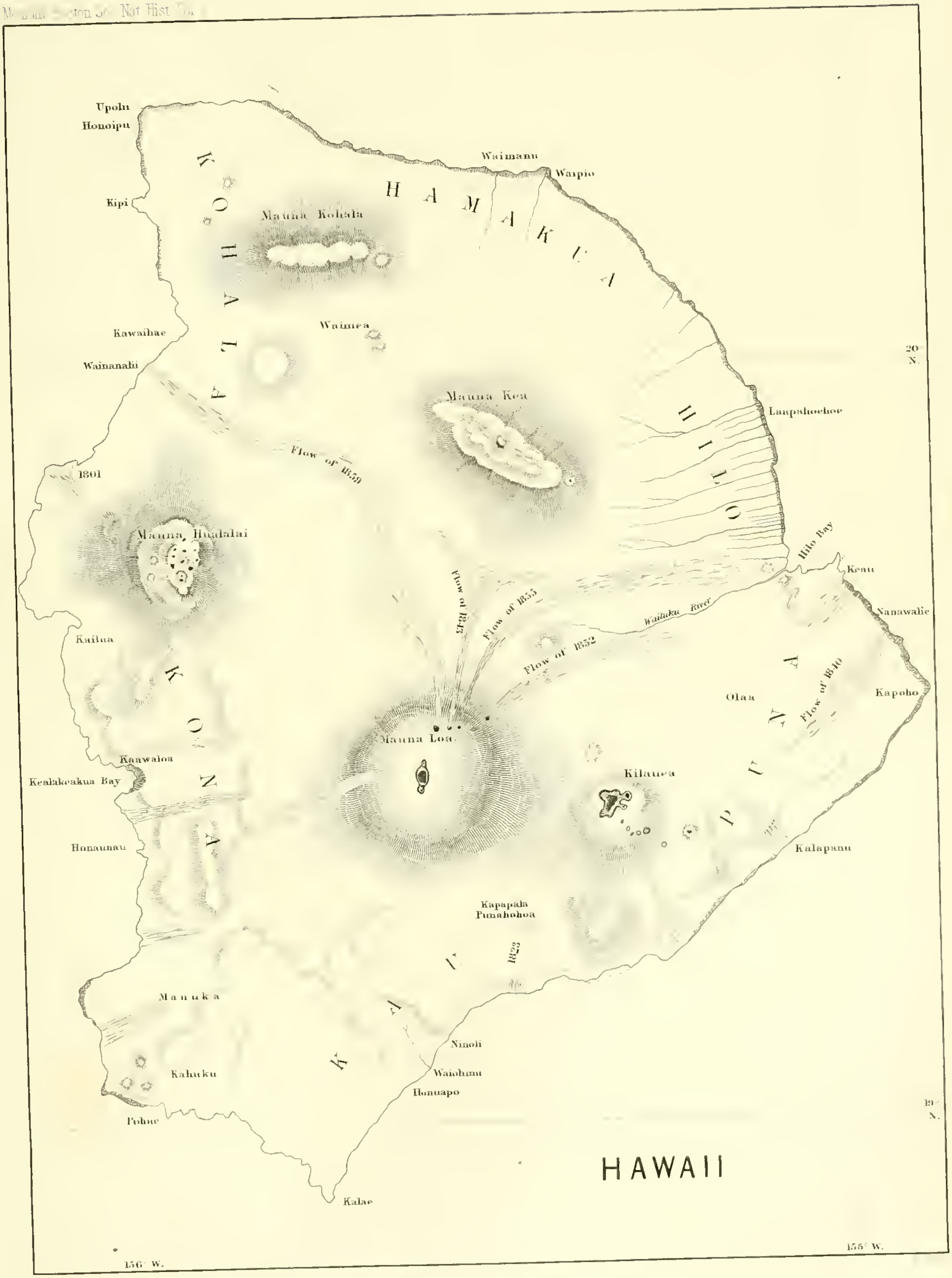
Nawiliwili
Kulaeokawai
Koloa
Wahiawa
Hanapepe
Waimea
Waiawa
Lapa
Puuoka Pele
Hina
Napali
Haena
Wainiha
Lumahai
Hanalei
LEHUA
Oku
KAULA
22 N.
160 W.


Kahuku
Laie
Waialua
Kaliwaa
Punaluu
Kahana
Kaneohe
Mokapu
Waianae
Kaala
Kailua
Waimanalo
Ewa
Konahuanui
Makapuu
Laeloa
Puuwaina
Moanalua
HONOLULU
Waikiki
Kaakaa
Koko Head
Leahi
OAHU.
158° W.


NIHOA
KAUAI
NIIHAU
OAHU
MOLOKAI
LANAI
MAUI
KAHOOLAWE
HAWAII
THE
HAWAIIAN GROUP.



MOLOKAI
Koolaupapa
Kalunaha
Halawa
LANAI
Kaokai
Mauna Eeka
Lahaina
Wailuku
Haiku
Maliko
Mauna Haleakala
Hana
MAUI
MOLOKINI
KAHOOLAWE
21 N
157 W.


Upolu
Honoipu
Kipi
Waimanu
Waipio
H A M A K U A
K O H A L A
Mauna Kohala
Waimea
Kawaihae
Wainanahi
20° N.
Mauna Kea
H I L O
Laupahoehoe
Flow of 1859
1801
Mauna Hualalai
Hilo Bay
Keau
Flow of 1843
Flow of 1855
Wailuku River
Nanawalie
Kailua
Flow of 1852
K O N A
P U N A
Flow of 1840
Olaa
Kapoho
Mauna Loa
Kaawaloa
Kealakeakua Bay
Kilauea
Honaunau
Kalapanu
Kapapala
Punahohoa
1823
K A U
Manuka
Ninoli
Waiohinu
Kahuku
Honuapo
19° N.
Pohue
HAWAII
Kalae
156° W.
155° W.

THE CRATER OF
KILAUEA
IN 1865.
SURVEYED AND DRAWN BY
WILLIAM T. BRIGHAM.
KILAUEA
1841
U S EXPL EXPED.
KILAUEA
1825
LIEUT MALDEN
Wooded
Gravel
House
Steam Cracks
To Hilo
Var. 5° E.
Var. 1° 30 E.
Var. 4° E.
Var. 26° 25 W.
Var. 2° 20 W.
Uwekahuna
Lava Lake
Lava Lake
1864
Ancient lava
Loose
Rock
Flow of 1864
Lava
Lava
1865
High Rock
Waldron's Ledge
Cracks
Shrubs
Crack of 1832
POLI O KEAWE
Deep Cave
Active Cone
To Kau
Deep Crack
Steam Cave
Crack
Burning Cone
Ka mahu pilu
Cathedral
Gravel and
Loose Stones
Smoke
HALEMAUMAU
Cave
Sulphur
Sulphur
Sandstone
KILAUEA IKI
Gravel Plain
Beds of Basaltic
Pumice
Gravel
Scale of Miles
SECTION of KILAUEA
Cathedral

MEMOIRS

READ BEFORE THE

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BEING A NEW SERIES

OF THE

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VOLUME I. PART IV.

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1869.

MEMOIRS

READ BEFORE THE BOSTON SOCIETY OF NATURAL HISTORY.

VOLUME I. PART IV.

XI. *On the Weapons and Military Character of the Race of the Mounds.* *By* Colonel Charles Whittlesey, Cleveland, Ohio.

Read March 20, 1867.

1. The Implements and Military Character of the Mound-builders.

In an article which was written in 1855–56 upon the Ancient Copper Mines of Lake Superior, and published in 1863 in the "Smithsonian Contributions to Knowledge," the implements used by the ancient miners in that region are described and illustrated. They are adapted principally to mining for copper. The tools found in the Ohio mounds were, almost without exception, intended for peaceful purposes, indicating a people whose habits were not warlike. They did not leave behind them in the Mississippi Valley, to my knowledge, any implements designed exclusively for purposes of warfare.

In the work of the Hon. E. George Squier, constituting the first volume of the "Smithsonian Contributions," their utensils, ornaments, and implements, composed of pottery, stone, shells, and copper, are fully described. They relate principally to domestic and agricultural uses, or to the chase. The race of the Mounds has left, however, numerous earth-works on the waters of the Ohio, that could be intended for nothing else than fortifications. After examining at least three fourths of those in Ohio, not less than one hundred in number, I have not seen conclusive evidence that any of them were attacked.

They must have been occupied by a people prepared for defence without being called upon to resist. It is a singular fact that weapons of war have not been found within these fortifications. Copper and stone axes are abundant, also copper chisels and gouges, but no exclusively warlike implements. There could have been no serious attack upon these fortifications without some trace of the assault being left upon the works.

It is a military principle which belongs to all systems of defence, in all conditions of warfare, through all ages and in all degrees of perfection in war, that permanent forts require a style of engineering for the attack similar to the system attacked. If there are moats, mounds, and parapets to be overcome, the besiegers must construct approaches, ditches, and embankments, or they will be exposed to the weapons of their adversary. When that is done, the works of circumvallation should remain visible upon the ground as long as the forts themselves.

I have seen no such counter-works near the ancient forts of Ohio. The lines of a besieging force would not be as prominent as the more deliberate works of the besieged; but in order to be successful, they must be so extensive and important that natural causes would obliterate both systems nearly alike. If the attacking party, except in the rare case of an assault, should succeed against a permanent fort, like the one at Fort Ancient on the Little Miami, in Warren County, Ohio, he must do it by demolishing a part of the line in order to get in.

I know of no case where the perimeter of an ancient fort has been cut through in this way. At Fort Erie, opposite Buffalo, New York, the parallels, traverses, and embrasures of the British lines are now, after an interval of fifty years, easily traced upon the ground. The injuries which they inflicted upon our lines by their artillery, and the breach made in our bastions by an explosion, still remain.

If these works are not disturbed, their general features will be visible centuries hence; testifying to all professional men that an attack was made. If no lines were found on the plain in front of Fort Erie, it would require no history to prove that it was not besieged.

The works investing Petersburgh, Virginia, will stand as long as the fortifications of the place, unless they are levelled by the hand of man. For centuries to come, military engineers will be able to find where the great mine was sprung and where breaches effected. Mounds of earth are the most imperishable of monuments. For a description of the Ohio fortifications of the era of the mound-builders, their ornaments, utensils, and implements, I refer to the exhaustive article of Mr. Squier, and to article 7 of vol. iii. of the "Smithsonian Contributions."

The race of the Mounds has left us as much in doubt in regard to their fighting implements as to their history. If they had used stones for this purpose to be thrown from slings, or as battering-rams, they should now remain upon the soil in the neighborhood of their forts. Large numbers of sculptured stones are found, but only a few that can be considered as implements of war.

Engraved shells, the teeth of animals used as ornaments, and wrought pieces of bone, are frequently found in and about the mounds. For warlike purposes, if they made use of stones, there must have been magazines of them collected within the works. The stone mauls which were used in mining operations upon Lake Superior are still found in great numbers on the spot.[1] Some of their copper arrow and spear-heads may have been designed for mortal combat, but most of them have a better adaptation to the purposes of hunting.

Implements of stone, flint, and copper that were evidently intended for cultivation of the soil or for domestic purposes are abundant, while those of a warlike character are very scarce. Some stone effigies of the human face are preserved entire, and many which represent animals; also a great variety of stone axes. The inference to be drawn from the absence of military weapons is, that they must have been fabricated of wood, and have decayed and disappeared.

[1] These mauls weigh from five to fifteen pounds, and are merely oblong water-worn boulders of hard, tough rocks. Nature has done everything in fashioning them, except the groove which was chiselled around the middle. They were collected from the smooth boulders of the lake shore, and from banks of coarse gravel that abound in the country. Most of them are trap; but the hornblende, syenitic and granitic rocks, furnish some. The ring or groove appears to have been cut for the purpose of attaching a withe, to be used as a handle, wherewith to swing the maul.

In one of the trenches on the cliff mine, north of the upper engine, one was found (see Plate xvi, fig. 5) with a root of cedar still twisted in the groove, but so much decayed that it fell to pieces. Dr. M. D. Senter, of the Cliff Mine, states that he saw it before being disturbed, and it was evidently the intention of the operators to use the twisted withe for a handle.

Although the mound-builders frequently constructed walls and mounds of rough stone, there is no instance where there are marks of cutting-tools upon them. Loose rocks are laid up rudely like a stone fence, or piled in heaps containing hundreds of cubic yards; but none of them are trimmed or cut. This could not have been for the want of metal implements, as their copper chisels are hard enough for such work. They had no iron or steel, but this is not necessary, as we know the pyramids were built with tools made of copper and tin.

Their stone axes are made from obsidian, greenstone, and porphyry, much harder than the common sand stone and lime rock of this country. The stone mauls of Lake Superior, like the axes of Ohio, have grooves around them for the purpose of attaching a withe to answer the purpose of a handle. Tools, whether of flint or metal, hard enough to sculpture obsidian and trap, were sufficient to trim and cut stone for masonry, if those who used them had chosen to do so.

Neither had this mysterious race discovered the art of metallurgy. All the copper implements they have left in the mounds and in the copper mines are made *cold wrought*, from native metal, never melted. We must not, however, hastily infer, because distinctive weapons of war have not been found, that the race of the Mounds were entirely without them. A club, somewhat resembling those which the South Sea Islanders use in their battles, was discovered in Geauga County, Ohio, many years since. It was of Nicaragua wood, very heavy, and being in a sound condition, was cut into chips and used for coloring cloth.

Although there is no necessary connection between this club, found upon the surface, and the wars of the mound-builders, there is some probability that it may have belonged to them. No metal tools have yet been discovered that can be regarded as shovels, picks, or hoes, yet extensive excavations made by them are visible all over the country. In a single earthwork in Warren County, Ohio, the estimated excavation and embankment is 600,000 cubic yards. They may have had picks of hard wood tipped with horn or bone.

Their shovels may have been of wood, like those found in the ancient mines of Lake Superior; or they may have been of copper, like the one figured on page 201 of Mr. Squier's work, plate 87, No. 4. Where ancient mounds have been opened, the appearance of the earth is mottled, as though it had been brought in bags, or in small parcels from different places. It must have been a difficult matter for them to work up the tough clay and hard pan of Ohio, but it is clear they had means to do it.

They frequently took earth for their mounds evenly from the surface, leaving no perceptible excavation. They did not quarry the solid rock, nor have they left on the loose stones which they used any marks of metal tools. But on Lake Superior their labors were applied to the hardest of rocks. Most of the tools they have left are adapted to that purpose only, though some of them are intended to cut wood, like those found in the Ohio mounds. There are rude axes, chisels, and adzes of copper, with mauls of copper and of stone.

In the ancient quarries or open cuts of the copper-bearing rocks, they have frequently left behind them copper wedges, in form precisely like the steel gad of the modern stone-splitter. Nothing like a metal pick has been found. They softened the trap rock by fires, breaking it up with their mauls and gads. The weapons which I now bring to notice are principally from Michigan, Wisconsin, and Canada. They may have been intended for the twofold purpose of hunting and mortal combat. There are also rude copper knives, occasionally discovered upon the surface in the same northern regions. None of them having, however, the finish of the spear-heads here described. These clumsy knives were, in all cases, beaten from nuggets of native copper, and were probably made by the present race of red men.

2. Dimensions of the Copper Weapons of the Mound-Builders.

Plate XVI, figs. 4 – 4[b]. *Copper Spear or Dirk from Ontonagon.* From Jno. S. Mullowny.

Found two feet below the surface ; a new implement, never used.

Length of blade and socket,	13.8 inches.
" " "	11.0 "
Greatest width of blade,	1.6 "

Straight, tapering to the point ; cross-section diamond shaped, with two ridges and two sharp edges.

Thickness,	.5 inch.
Breadth of socket outside,	1.2 "

Thickness of socket metal, about one tenth of an inch, not strong enough for a lance-head ; open one fourth of the circumference.

All the sockets are made by flattening the copper cold and bending it over, leaving about one fourth of the front open.[1]

Plate XVI, figs. 7 – 7[d]. *Copper Spear-Head from Kilbourn City, Sauk County, Wisconsin.* From A. B. Wood, Mining Engineer of Copper Harbor, Lake Superior.

Found in a mound about one foot below surface.

Length of blade and socket,	12.0 inches.
" " "	9.0 "
Greatest breadth of blade,	1.6 "
Breadth at middle,	1.1 "
Thickness,	.4 "
Breadth of socket,	1.0 "

Tapers from socket to point regularly. Cross-section a flat triangle. The flat side is with the open side of the socket, the ridge extending along the back of the socket.

Plate XVI, figs. 8 – 8[a]. *Copper Spear-Head, Brockville, Canada West.* From Dr. T. Reynolds.

Length over all, 12 inches ; no socket, but a pointed shank ; tapers slightly to near the point, and then forms a blunt end. Breadth where the cross-section is given, 1.8 inch.

With this was another, in all respects similar. Length, 9 inches. These were fourteen feet below the surface, with bones, copper knives, and a spade or gouge.

[1] Plate XVI, figs. 3 – 3[a]. Copper chisel from Ontonagon. Jno. S. Mullowny.

Length along the middle, 12 inches.

Greatest breadth measured through the implement, 2 inches.

" " measured over the ridge, 2.25 inches.

" thickness, .25 inch.

Height of ridge above the surface on which the implement may rest, .8 inch.

The chisel had not been used, since neither the cutting edge nor the head is battered. It is bent up longitudinally from near each end in the manner shown by the cross-section, (fig. 3[a]). The object in giving it this form must have been to stiffen it and thus save metal. The contrivance speaks well for the ingenuity of the maker.

PLATE XVI, figs. 6 – 6[a]. *Copper Spear-Head found near Cincinnati.* From R. Buchanan, Esq.

Length, 8 inches ; neither socket or shank; has a neck like the flint arrow-heads. Greatest breadth, 1.6 inches. Breadth where the cross-section is given, 1.2 inch., does not taper at the point, but gradually, and then has a blunt end like the Brockville spears.

PLATE XVI, figs. 2 – 2[b]. *Copper Arrow or Javelin Head, Copper Falls Mine, Lake Superior.* From S. W. Hill.

Found in ancient mine pits several feet below the surface.

Length of blade and socket,	4.6 inches.
" " "	2.6 "
Breadth of blade at middle,	.9 "
" " socket	.9 "

Cross-section flattened, edges sharp ; flat side to the back of the socket, a ridge in front. Thickness of the blade, three tenths of an inch, well finished ; more than one found at this place ; one of them with a part of the handle in the socket, well finished.

PLATE XVI, figs. 1 – 1[c]. *Copper Arrow or Javelin Head, Oak Orchard, Oconto County, Wisconsin.* From Mr. Windross.

Found on the surface.

Length of blade and socket,	4.0 inches.
" " "	3.0 "
Breadth of blade at middle,	.9 "

Cross-section flattened, flat side to the front or open part of the socket.

Breadth of socket,	.90 inches.
Thickness of blade,	.15 "

Rudely finished ; a small round hole in the socket to fasten on the handle.

In point of workmanship the tools of the modern Indians are always inferior to the copper ones of the mound-builders and the ancient mine workers.

Some tools, which resemble a knife in form, were used, not as cutting instruments, but apparently for cleaning and dressing skins.

Among the implements described by Mr. Squier, there is the rude spear-head of copper, above referred to (Plate XVI, fig. 6), found near the city of Cincinnati. This is the only reported instance in Ohio, of an ancient weapon that might have been used in war. It is not from a mound, but in the vicinity of mounds, buried two feet beneath the surface. The mode of attachment by means of a neck instead of a socket, is different from the lance or spear-heads of the North.

There were also discovered, by Dr. Reynolds of Brockville, Canada, on the banks of the St. Lawrence, at a depth of fourteen feet below the surface, three rude copper spears, one of which is described above, (Plate XVI, fig. 8). A clumsy copper knife and human bones were found in the same connection, also a spade-like implement already alluded to.

These spears have a tapering shank, coming to a point, intended to be driven into a handle like those of pitchforks and hoes.

Besides these now referred to, I know of no copper spears or arrow-heads that may be considered ancient.

If the collection of Dr. Reynolds originally belonged to the race of the Mounds and the ancient miners, the remarks I have already made upon the use of such weapons will apply to them. They may have been designed for dispatching wild animals only; they are not so exclusively warlike as to warrant us in coming to a certain conclusion that they are implements of war.

In Europe, ethnological writers distinguish the progress of mechanical arts among men as the "Ages of Stone," of "Bronze," and "Iron."

In the Western States the ancient inhabitants did not follow this order of progress, or rather did not progress, but relapsed. Here the age of copper corresponds to the European "Age of Bronze," to which the Age of Stone has here succeeded. The only metals the mound-builders have left us are native silver and copper. They know no alloys of the latter metal, as the Eastern nations did. Copper was sometimes melted accidentally in burning the rock, as it is now upon the calcining pile; but the old miners never turned this fact to account by melting ore for the purpose of refining it, neither did they possess metallurgy enough to reduce lead ore.

On the old continents, where only the ores of copper were known, having none in a native state, they were compelled to melt it. Thus they soon discovered the alloys of tin, lead, and zinc, of which their mechanical tools were made. Here the ancients had nothing harder than native copper. The Age of Stone is generally considered as the most ancient and primitive condition of man. This is represented by stone-axes, but more particularly by flint implements, such as knives, hatchets, arrows, and spear-heads; but the flint implements of Ohio appear to be almost exclusively the work of the present race of Indians.

No one can affirm that there were not human beings on this soil before the race of the mounds; for although there are no sufficient evidences of such a people, modern researches all tend to increase the antiquity of man. Where these investigations will terminate it is not easy to divine. The flint implements of the recent drift period in England and France suggest the idea of man's presence on the earth, at a period as remote as the era of the Mastodon, Megatherium, Megalonyx, and many other extinct animals.

But in this country the most ancient tools are no more ancient than the artificial structures of man. Among those which were wrought of stone, there are very few which are conclusively shown to belong to the mound period. Of those which Mr. Squier has described, nearly all were fabricated from quartz or obsidian. Very few of the flint implements which are so abundant in the Northern States can be traced to the Mounds. No race has been known to be so low in mechanical skill as not to make tools of flint. Such tools are an evidence not of an elevated but a debased condition.

The Esquimaux of the North and the digger tribes of California are skilful in developing perfect arrow-heads from nodules of flint. All the contrivances of the race of the Mounds intended for practical purposes, display skill of a higher order. In the instances where cutting implements of stone are found in their works, they do not appear to have been for general use either in peace or war.

This people had a passion for the ornamental; they were also of an agricultural genius, which indicates peace and quietness. There are abundant evidences that they were highly religious. Their native ingenuity was not exhausted in contrivances for successful hunting, but for successful cultivation of the soil. About one half of their great earthworks appear to have been connected with religious observances or with reverence for the dead. Preparations for war seem to have been with them a secondary object. Perhaps their forts were not erected until after a long residence here, when they were threatened by warlike neighbors.

The period during which they were compelled to turn their attention to military affairs was probably short; and, when their preparations were made, they may have withdrawn further south without a vigorous defence.

The conclusion at which I arrive is, that we have not yet discovered the fighting implements of the race of the Mounds. Although there is no satisfactory evidence that they engaged in wars, it would be against all history and the inherent pugnacity of the human race to conclude that they had none. A people without wars and warlike preparations has never been known. The race of the Mounds constructed a large number of strong and permanent forts, most of them located with military skill, so as to make the most of the position for defensive purposes.

We find no proof that these works were called into requisition for defence, but the fact of their existence shows that they were prepared for war. If so, they must have had weapons of offence and defence, but what they were we cannot affirm. Their stone axes may have served the double purpose of battle-axes and of cutting instruments, but a people thus highly advanced in mechanics must have had something better. Their copper knives, daggers, and spears are not strong enough for the purposes of a lance or spear intended to stand the shock of armed men. Nothing resembling a sword has been discovered.

The sharp instruments with sockets and shanks, which I have presented, were doubtless designed for short handles, no larger than could be used in one hand, like a dirk or dagger. The smaller ones could also be used as arrow-heads, and all of them are better fitted for hunting wild animals than for military purposes.

I have referred to the small number of flint knives, and arrow or spear-heads of stone found in the mounds. Most of the flint implements are discs, or oval cutters with curved edges. Most of the flint knives and arrow-heads, which are so plentifully found at the West, appear to belong to the Indians, who did not use them as spears or lances.

Some of the flint implements might have formed the cutting part of a war club, or wooden battle-axe. There are many modes known among uncivilized tribes for making a formidable weapon out of wood and sharp stones or bone, in the nature of a club. It is singular that so few relics of a warlike character are found in the mounds, while so many forts exist in the country. If the tumuli were erected in honor of martial heroes, there should have been in their tombs the warlike implements which they used in battle. Instead of this, most of the relics which have been discovered are mere ornaments and symbols, the latter of a religious cast.

3. Fortifications of the Aborigines.

There are those who attribute the old forts to the red men, which the white race found in possession of the country. Objections to this view are so numerous that it will not bear examination. The Indian mode of warfare as against their own race, consisted in surprises and retreats, not in persistent attacks or defences. To open fighting they have always been averse. In the first expeditions of Champlain against the Iroquois, south of Lake Ontario, in 1609 and 1615, he found their forts to consist of wooden barricades only, made of posts, with cross timbers to hold them together. A town he attacked in Western New York, probably at the outlet of Canandaigua Lake, had pickets thirty feet high with galleries on the inside near the top, from whence the Senecas shot their arrows.

After the Indians had seen how the Spaniards and the French erected stockades, they, in a few cases, undertook to protect themselves in the same way. With his stone axe and even with the tomahawk and squaw axe, which the whites furnished him, he could do little towards cutting down forest trees for pickets. The stockades which the Iroquois constructed, to resist the French at Onondaga, were made by burning off logs to a proper length, which were but slightly set in the ground. They were without trenches. It is not a part of the Indian character to provide for the future by present labor. The Onondaga fort was probably planned by some Englishman.

It had a rectangular form with four bastions; but no mention is made of parapets or moats. It was built of large logs set in the ground in double ranks, so as to break joints. On one side the line was composed of pickets thirty to forty feet high, with narrow spaces between them. The Indians in this case did not attempt to defend their forts against the French, but burned them and fled. They had also stakes and brush so interwoven as to make a good defence against Indian weapons. Champlain states that they had stone axes, and only a few miserable ones of iron, to cut timber for their works.

His Indian allies, the Hurons of the north shore of Lake Ontario, were not at all inclined to attack even this temporary fort of the Iroquois, and he was obliged with less than a dozen Frenchmen, who had arquebuses, to do what was done. The French expedition under De Nonville by way of Ironduquoit Bay, against the Senecas of Genesee Valley, in 1687, found them in villages, with wooden defences similar to those at Onondaga. In 1696 when the Count Frontenac marched to the Onondaga castles above Syracuse, the cabins of the Onondagas and of the Oneidas were protected by a triple palisade which was very high, but no mention is made of ditches. A people who once possessed it would never have lost the art of earth-work defences, nor would the tradition of wars and battles, occurring in connection with their ancient forts, have been forgotten.

Very likely the ancient people who fortified on the shores of Lakes Erie and Ontario, were not the same who occupied the valley of the Ohio; but it is highly improbable they were what we call the Aborigines, whose strategy consists in rapidity and concealment. It is very seldom they engage in a prolonged battle, even among themselves.

Their habits of war and their precarious mode of supply do not enable them to congregate in great numbers, or to remain a long time around a besieged place. The ancient forts of the mound-builders are as impregnable to assaults of our own race as to those of red men.

EXPLANATION OF PLATE XVI.

[It should be stated that it was the intention of the Author to illustrate only weapons used for war or the chase. As the drawings of figs. 3 and 5 were sent upon the same sheets as the others, they were placed in the hands of the engraver before the Author was aware of it — two explanatory notes concerning them have therefore been inserted in the text]. The figures are all reduced one third.

Fig. 1. — Arrow or Javelin head from Oak Orchard, Wisconsin; 1*a*., side view; 1*b*., cross-section through *a-b*.; 1*c*., cross-section through *c-d*.

Fig. 2. — Arrow or Javelin head from Copper Falls Mine, Lake Superior; 2*a*., cross-section through *e-f*.; 2*b*., cross-section through *g-h*.

Fig. 3. — Chisel from Ontonagon; *3a.*, cross-section through *i-j.*

Fig. 4. — Spear or dirk from Ontonagon; *4a.*, side view of the same; *4b.*, cross-section through *k-l.*

Fig. 5. — Stone Maul from Cliff Mine, Lake Superior.

Fig. 6. — Spear-head from the neighborhood of Cincinnati; *6a.*, cross-section through *m-n.*

Fig. 7. — Spear-head from Kilbourn City, Wisconsin; *7a.*, side view of same; *7b.*, cross-section through *o-p.*; *7c.*, cross-section through *q-r.*; *7d.*, cross-section through *s-t.*

Fig. 8. — Spear-head from Brockville, Canada West; *8a.*, cross-section through *u-v.*

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XII. *On the Distortion of Pebbles in Conglomerates, with Illustrations from Rangely Lake, in Maine.* By Geo. L. Vose.

Read January 3, 1868.

THE attention of geologists, both in Europe and in this country, has recently been directed to certain changes which seem to have taken place in masses of conglomerate, by which the included pebbles appear to have been altered both in outward form and in their mineral character. The late Dr. Edward Hitchcock, and his son, Mr. Charles H. Hitchcock, have called attention in several different publications, since the year 1860, to localities in Maine, Vermont, Massachusetts, and Rhode Island, where this metamorphism is said to have occurred. The above-named geologists maintain: First, That the pebbles of certain conglomerates have been elongated, flattened, and bent, since their consolidation into rock, *i. e.*, since they were pebbles, — and also, that the mineral nature of some of the pebbles has been materially changed during the process of compression, to which the flattening is believed to be due. Secondly, That the operation has, in some cases, been carried to such an extent that the pebbles have been entirely flattened out, and changed into the siliceous laminæ of talcose and micaceous schists, while the cement has been converted into mica, talc, and feldspar. Finally, The extreme result of this process of metamorphism is stated to be granite, and instances are adduced where the various changes may be traced in unbroken connection — a single undivided ledge passing from an undoubted conglomerate to a rock, which by itself would be called granite; so that, as the Messrs. Hitchcock observe, the conclusion is forced upon us that the granite was formed out of the conglomerate. The principal agent in this operation is considered to have been severe compression, acting at right angles to the plane of the dip and strike; and the materials are supposed to have been at the time in a plastic condition.

With regard to the conglomerate referred to by the above-named geologists, at Purgatory, near Newport, Rhode Island, it was held by Dr. Charles T. Jackson and Prof. Wm. B. Rogers, and by Mr. B. S. Lyman of Philadelphia, that the arrangement of the longer axes of the pebbles into parallel planes is such a one as they would naturally assume from the action of waves upon a beach; that the flattened form of the pebbles was due to the schistose structure of the rock out of which they were formed; and that even an apparent bending of one pebble around another might result from the accidental juxtaposition of a round pebble and a pebble formed from a part of a sharply folded bed of schist. It was also held by these gentlemen to be very improbable that the pebbles had been in a plastic condition since their formation.

The distortion of the pebbles in the Newport conglomerate, is by no means extreme, and this locality alone might not be sufficient to place the conclusion, that the pebbles had been altered in form, beyond doubt; but the locality to which we are about to refer, seems to leave no room whatever for question as to the extreme change which the pebbles have undergone, both in shape and mineral character; and we believe that the nature of the agent which produced the alteration, and the condition of the materials at the time they were altered, may both be understood with a considerable degree of certainty.

Mr. Charles Hitchcock, in his reports upon the geology of Maine, refers to the conglomerate at the east end of Rangely Lake, in the upper part of Franklin County, as affording good examples of pebbles which have been distorted and altered; and it would certainly be hard to find more satisfactory evidence of this sort of geological metamorphism. Upon the ground the evidence of severe compression, at right angles to the plane of the dip and strike of the beds, is entirely conclusive. Exposures of hundreds of square feet may be seen where every pebble, granite, sandstone, schist, and quartz, has been flattened, and the whole mass of pebbles and cement so jammed and crowded together, as to settle the question as to the direction and nature of the force which has been at work.

The conglomerate at Rangely Lake consists of a series of nearly vertical beds, having a direction, or strike, of N. 65° E., S. 65° W., (magnetic var. 15° W., in 1867), and a breadth, measuring across the upturned edges, at right angles to the strike, of about a mile and a half. How far the formation extends in the direction of the strike, N. E. and S. W., has not been ascertained; it crosses the eastern end of Rangely Lake, and is well seen at the mouth of the stream flowing into the head of the lake from Long Pond. The conglomerate is bounded upon the north-west by schists, having the same strike, and a vertical dip; which latter, however, decreases in going N. W., dipping about 70° E. at five or six miles from the conglomerate. Upon the south-east the conglomerate passes into, or is bounded by, a schist having the same strike, but dipping about 45° S. E. This change in the dip, from vertical to 45°, seems to occur suddenly, at or near the small stream called Saddleback Brook, and most likely indicates a fault at that place. The conglomerate is not known to appear either east or west of the adjoining schists; and we should hardly expect that it would, for we cannot suppose that the whole width of the conglomerate, one and a half miles measured across the upturned edges of the vertical beds, represents only the simple thickness of the formation. It is more likely that the conglomerate alone embraces a number of closely compressed folds, of which the summits have been denuded. These upturned ledges present successive beds of slate, of schist, free from pebbles, and beds almost wholly made up of pebbles; such beds being from a few inches to several feet in thickness, and joining each other in some cases in a sudden manner, and in other instances in a transitional way. In some of the beds the pebbles are nearly all large, *i. e.*, from three to six inches in diameter; in others they are smaller, from a fourth to a half of an inch in diameter, and in others as fine as gravel. The pebbles may be seen in all conditions, from being very distinct and embedded in a separate matrix, to being so undefined as with difficulty to be made out. In some cases, a fresh fracture shows pebbles so like the matrix, both in color and in mineral character, as to be indistinguishable at a distance of half a dozen feet; the whole mass appearing like a granite, or a syenite, while it is certainly an altered conglomerate. It is to be observed, however, that upon the ground no such thing occurs as a regular progression from conglomerate to granite; but the beds in various degrees of alteration occur, one after the other, in no apparent order.

The Messrs. Hitchcock maintain: First, That the pebbles have been flattened and distorted by compression, acting at right angles to the plane of the dip and strike; and of this we think there can be no doubt whatever. The distorted pebbles occur where the beds have been folded into waves and jammed closely together. Such a folding as this could result only from an intense horizontal force, and such a force would be precisely that needed for flattening and indenting the pebbles as we see them upon the ground. The parallel vertical position of the beds, and the flattened pebbles, with their planes parallel with the bedding, we regard as the results of a common operation; and that operation an intense horizontal compression, similar to that which has produced the more or less closely folded waves of the Appalachian Mountains.

The second position of the Messrs. Hitchcock — that the materials at the time of their compression were in a plastic condition — has been strongly objected to, and we think upon good grounds. The statement as made by them, however, has undergone a great modification since 1860. At that time a plasticity as great as that of moistened clay was suggested. At the meeting of the American Association at Burlington, in 1867, Mr. Charles Hitchcock proposed a plasticity perhaps no more than is implied by a thorough, warm, aqueous interpenetration of the masses. Just what sort of a physical condition this last-named plasticity may denote, we do not know; but inasmuch as it is a less plastic condition than that of moistened clay, we believe it to be a more likely one, and we believe it to be more likely still that the materials have not been plastic at all; but that they were altered both in form and mineral character, while in what may be called a rigid condition. It is well known in the arts that complete changes, both of external form and of internal physical structure, may be produced while bodies are what may be properly called rigid. Mr. Tyndall, in his work upon the Glaciers, refers to certain quartz stones in the Museum of the Government School of Mines, in London, which have been subjected to enormous pressure, and which have become mutually flattened and indented: some of them, he observes, have yielded along planes passing through them, as if one half had slidden over the other, but being strongly reattached; others, which have endured pressure at a particular point, are fissured radially around this point; a case which may be considered illustrated in Pl. XIX, fig. 1; and he remarks, that the whole collection is an instructive example of the manner and extent to which one of the most rigid substances in nature can yield on the application of a sufficient force. Mr. Tyndall further states, that the molecular arrangement of *glass*, pressed by a sufficient weight, is actually changed, — the fact being shown by the action of such squeezed glass upon polarized light; and he considers that a prism of glass might be compressed under a counter and lateral restraint great enough to keep it from flying to pieces, so that it should be flattened, partly through rupture, and partly though molecular yielding, so as to change its form, and yet present a firmly coherent mass when removed from its confinement. Now we believe this to be the condition under which the conglomeratic pebbles have been placed, namely: immense but extremely gradual compression, and at the same time a counter-pressure sufficient to force the broken mass together in a new form. The crushing and regealing of ice is an operation somewhat of the same kind, and though we may not have in rock the internal liquefaction, which Mr. Tyndall's experiments showed in ice, we do have an internal heat developed in the rock by pressure. Mr. Sorby states that his microscopic investigations proved that mechanical force had been in certain rocks resolved into chemical action. What more can be needed to produce the distortion seen in the pebbles, than a force great enough to break them, and a counter-force sufficient to bring the parts near enough for adhesion in a new position, to which we may add heat and its correlated chemical forces? It is a well-known fact, that the old-fashioned monumental tablets seen in burying-grounds, consisting of a horizontal slab, generally of marble, supported only at the four corners, and thus subject in the central part to the action of its own weight, become after a few years deflected to a considerable extent. Here we have a rigid piece of rock actually bent, under a force and in a time which, geologically considered, are utterly insignificant. Engineering science is full of examples where permanent changes of form, of size, and of internal structure, are induced upon rigid bodies under restraints and by forces of various kinds; and indeed iron in some cases passes from a fibrous to a crystalline condition simply from terrestrial magnetism. In metallurgical operations certain poor copper ores are brought to a heat, *which must not be great enough to melt them*, when the copper, which before existed as copper pyrites and was more or less uniformly disseminated through the mass, is found as a kernel in the interior; while portions of the iron and sulphur contained in the crude ore are driven outwards. Many of the so-called contact changes, seen in the neighborhood of dykes, were certainly produced while the rock was in what we should call a rigid state. Such facts illustrate the remark of Gay Lussac — "Dans un corps solide les molécules peuvent changer le position, et prendre la forme crystalline;" and also that of Keilhau, that "Solid unorganized bodies are capable of changing their structural and chemical characters, by means of slowly working causes in the solid rock, and of assuming forms which they did not before possess." We must indeed suppose that molecular motion is always going on in rocks, inasmuch as this motion is a form of heat, and as no rock is entirely cold. Pressure causes in some cases a quicker molecular motion, or a greater heat, or a less rigid condition, under which a new physical structure may be induced quicker than when the body is more rigid, or colder, or more at rest molecularly.

The pebble shown in Pl. XIX, fig. 1, would seem to have been rigid, to have been so sharply broken; we should hardly call a body plastic that became ruptured in such a manner. As a general rule, however, no such decided breaking is seen; and from the nature of the assumed operation we should not suppose that it would be. Mr. Tyndall remarks, regarding the moulding of ice into curved forms, that in every case the ice in changing its form was crushed and broken; but that if instead of three moulds three thousand had been used, or better still, if the form of a single mould had been changed by extremely slow degrees, no rude rupture would be apparent; the ice would behave as a plastic mass. And, again, he observes: "How far this ice . . . is bruised and broken, and how far the motion of its parts may approach to that of a truly viscous body under pressure, I do not know. The critical point here is, that the ice changes its form, and preserves its continuity, during its motion, in virtue of *external* force. It remains continuous whilst it moves, because its particles are kept in juxtaposition by pressure, and when this external prop is removed, . . . the analogy with a viscous body instantly breaks down." Suppose now that these pebbles, in a perfectly rigid condition, are submitted to one of those enormous pressures, which geology has the right to call upon, for a hundred thousand years; and suppose that such a pebble should yield to the force, and break, ten times each year; and after each fracture should be jammed together again in a slightly altered form. If the pebble is obliged to bend in the whole time through the space of an inch, it would yield at each fracture the one millionth only of that space. What difference could we see between such a movement and that of a really plastic mass? We believe that such a pebble would change its form both by rupture, where subject to tension, and by molecular yielding, where subject to compression, and, as Mr. Tyndall says of the ice, would preserve its continuity, during the change of form, in virtue of *external* force. It is plain that no rigid pebble can withstand more than a certain force without yielding; and it is also plain that simple pressure, if great enough, will compact loose materials into solid rock; and we hold that in the folding up of vast strata, both this breaking and this reconstructing force are necessarily present.

Mr. Sorby states, that the fine grained slates containing minute rounded grains of mica, seldom over the one hundredth of an inch in diameter, which under the microscope are seen to be composed of many laminæ, which when they lie parallel to the cleavage planes, are undisturbed, but when perpendicular to those planes, are distorted and bent; and he further states that calc-crystals, filling the cavities of organic bodies in uncleaved limestones, have their crystalline cleavage planes almost invariably straight, while in a highly cleaved specimen, the calc-spar is bent and crushed; showing, as he remarks, that the compressing force acted so intensely and so gradually, as to change the molecular arrangement even of calc-spar, and bend it.

It is hard to understand how a portion of the pebbles could have been so very much distorted, as we see them, while others nearly adjacent should have been altered but little, or none at all. We often find in these conglomerates schistose pebbles, with the laminæ at right-angles with the general plane of the flattening. This has been considered as evidence against the idea that a compressive force has flattened the pebbles; as it is said that such a force would develop a lamination in these slaty pebbles parallel with, but not perpendicular to, the general flattening. Pl. XVIII, fig. 2, may be considered as an answer to this objection, for the bending and indenting of the upper pebbles is too plain to leave any doubt as to the direction of the force; it is equally plain that such a force could not have produced the lamination shown in the lower pebbles, which must therefore be regarded simply as the original schistosity of the rock from which those pebbles were made.

In some cases, the form of the pebbles has been altered without any change in the mineral character; and in other instances the mineral nature seems to have been entirely altered, while the form of the pebble remains unchanged. Possibly where the cement is deficient, so that the pebbles are at once brought in contact, the change of form will take place, and the force, relieving itself in such a manner, will not produce a metamorphosing heat, while, when the cement is abundant, a heat will be developed in the mass before the pebbles are brought together, and mineral changes will result, without so marked a distortion of the pebbles. If we should fill a strong iron box with leaden bullets, and fit a plunger into the top of the box, and force it down sufficiently, we should distort the bullets, which would become flattened at the points of contact, until the interstices were filled up; and so long as the force was allowed to relieve itself in this manner, we might have no great heat developed; but if we placed a few bullets, at a distance from each other, in a box of sand, and compressed the sand, the force would be applied to the bullets in a sort of hydrostatic way, and would not tend to distort them, but would, after the sand was somewhat consolidated, apply itself to the production of a heat sufficient to alter the whole mass mineralogically. The analogy is, to be sure, not very close between the natural and the artificial process; but as the pebbles are generally harder than the cement, certainly so in the early stages of the conglomerate, it may have some value. If the conglomerate was compressed while the cement was still in an incoherent state, of course the matrix would be affected much more than the pebbles; but if the strata were not folded up until the whole mass was rigid, the pebbles and the cement would have to bear the compression more equally.

It has been remarked, that certain granitic rocks have been produced by the metamorphosis of conglomerates. The Rangely conglomerate has in some cases certainly been converted into a homogeneous crystalline mass, resembling syenite; and we believe that a severe compression continued for a long time will account for all of the various phenomena seen at the above-named place. The conglomerate certainly commenced as an incoherent mass of pebbles and finely comminuted mineral matter, which has been consolidated and folded into a series of closely compressed waves, the summits of which being denuded have left the upturned nearly vertical beds as we now see them. We believe that such compression continued long enough after the beds assumed the vertical position to flatten and indent the pebbles; and that it not only produced the dynamical results, but, by the development of heat within the mass of the rock, furnished the means for chemical changes. We believe further that hard and rigid pebbles may, under such a force, be bent and flattened, without becoming what would be called plastic, in the same way as fossils are often distorted.

Notes Relating to the Plates.

The figures in Plates XVII and XVIII are of the natural size; those on Plate XIX are of one half of the natural size. The dotted line in each figure represents the direction of the strike; the pressure is supposed to have acted at right-angles to that line. Pl. XIX, fig. 2, being sketched from a displaced fragment, has not the line of strike drawn upon it.

In Pl. XVIII, fig. 1, the pebbles marked *a* and *b*, are coarse-grained, hard, and granitic; the other stones are of a softer material.

In Pl. XVIII, fig. 2, we have an example of pebbles considerably distorted, while immediately adjacent are schistose fragments with a lamination at right-angles to the position it would have if produced by the force which has bent the other stones.

Pl. XIX, fig. 1, shows a large, light-colored, fine grained, siliceous pebble, apparently fractured in bending. The stones marked *a* and *b*, are of granite.

Plate XIX, fig. 2, shows a large, fine grained, dark-colored rock, apparently distorted by being pressed against the rounded pebbles, which are of granite. Between the larger round pebble and the upper stone occurs a group of five distinct fragments, all of which seem to be distorted. The dotted line in this figure shows the direction according to which the smaller stones, and the particles of the cement, are arranged.

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XIII. *Notes on Birds observed in Western Iowa, in the months of July, August and September; also on Birds observed in Northern Illinois, in May and June, and at Richmond, Wayne Co., Indiana, between June third and tenth.* By J. A. Allen.

Read June 3d, 1868.

A CAREFUL examination of our present data concerning the distribution of American Birds, will soon fully convince one that the range in the breeding season must form the basis for defining the limits in latitude of the different avi-provinces and faunæ; at other seasons the migratory species are rarely localized for any considerable period, and hence, though forming an important element in the faunal features of the regions they visit, they cannot properly be considered as inhabitants of any of them. This becomes the more evident when we consider that though a given species may be represented for weeks at certain points in its migratory range, it is only by a succession of individuals and not by a single set.[1] Those birds which seek high northern latitudes in the breeding season, and sub-temperate or tropical in winter, pass nearly two thirds of the year in long journeys, rarely pausing for any long interval, beginning slowly to retrace their steps almost as soon as they reach their southern limit. Their breeding country, then, however short their residence there, is their only true home; and here it is that their influence is most positive. This is no less the case with those species whose migrations are less extended, and which are, to a greater or less degree, winter residents in stations not far remote from their summer homes.

In studying the distribution of the birds in any country, the investigator is almost at once checked by the lack of proper data. Even in countries where ornithology has been long cultivated, as in Europe and the older portions of our own country, is the deficiency hardly less than in regions more slightly known. The cause of this is, of course, the slight lapse of time since the geographical distribution of animals has come to be critically studied, and the present want of interest in the subject among many who could otherwise greatly aid its advance. At present we do not know with sufficient exactness the avi-fauna of any considerable region, even when we know pretty definitely all the species occurring there.

[1] As might be naturally supposed, in migratory species ranging far to the north in the breeding season of any locality where they breed abundantly, those that arrive first in spring are not those that remain and breed at that point. The difference in size so well known to characterize birds of the same species, breeding in different latitudes, affords the means of demonstrating this; we have found that in several species those that first arrive in Massachusetts are, in general, very appreciably larger than those that arrive later, or than those that remain through the summer. This has been especially noted in *Turdus migratorius*, *T. Swainsoni*, *T. Pallasi*, *Dendrœca æstiva*, *Spizella socialis*, and in other sparrows and warblers, and in some of the *Tringeæ*. It is also fair to infer that in general birds do not arrive at their breeding stations long before they set about the duties of incubation, since those species that pass but a little to the north of Massachusetts are noticed to pair and commence building their nests within a few days after the species is first noticed there, while *D. æstiva*, and the few other species which range to the Arctic Circle, are seen for nearly a month before they begin nesting, and do not breed earlier in Massachusetts than they do about Hudson's Bay, or in the valley of the Mackenzie River. Again in autumn we find that in general the individuals *last* seen are larger than summer specimens, and in most cases that winter specimens, in many so-called resident species, are larger than those found at the same place in summer; also that unusual visitors from the north are generally rather smaller than the average of the species, as in *Pinicola enucleator* (*P. canadensis* Cab.) *Ægiothus linaria*, and others. The migration seems to be by a general swaying southward in winter, and northward in summer, of all the representatives of the species, those found farthest north or south in winter being also those living respectively farthest north or south in summer; though there is, doubtless, a greater tendency in the more mature and vigorous birds to seek higher latitudes, especially in the breeding season, than the younger and weaker. All experienced collectors of birds, moreover, are well aware that those that first arrive in spring are of brighter tints than those coming later, and are in every respect apparently the most perfect representatives of their kind.

It is hence to be much regretted that competent observers should still give us merely nominal lists, unaccompanied by notes on the relative abundance and season of occurrence of the different species, and that lists of collections derived from little known countries should be published, as too frequently happens, without stating, when known, the date and exact locality of capture of the specimens. Observations on thirty or forty of the species most common, made in the breeding season, at a hundred or more different localities in the States east of the Mississippi, would enable us quite definitely to indicate the different avi-faunal areas of this region; and not till then, or at least till our data are vastly multiplied, can we arrive at wholly satisfactory conclusions. This number of complete lists would be, of course, far better, and if extended, with the same minuteness, throughout the continent, would afford us not only exact data on faunæ and the general laws of distribution, but, of course, would give us the means of determining the exact range of each species, at all the different seasons. Hence we deem no apology necessary in bringing forward the following lists of birds observed in the breeding season, though in some cases so incomplete.

The distribution of marine animals, from investigations made by Dana, Forbes, and others, seems greatly dependent on temperature. Prof. A. E. Verrill[1] has also pointed out the close coincidence of the boundaries of the Canadian and Alleghanian faunæ, as generally received, with the line of mean temperature of 50° F. for the months of April, May, and June; at the same time urging that the distribution of birds in latitude is chiefly influenced by the temperature of the breeding season. From the coast westward to Lake Michigan, the almost exact accordance of the southern limit in the breeding season of several species of the Canadian fauna, and of the northern limit in the same season of several species of the Alleghanian with this line, following its southern bendings in crossing mountain ranges and retreating with it northwards as it follows up the river valleys, is most noteworthy, and seems to point to a definite and intimate connection between the two phenomena. In other cases,[2] and in other classes of animals, we have, even from our present scanty data, traces of a similar correspondence; so positive, indeed, as to lead us to infer a general relation between the limitation of species in latitude and altitude and temperature. On the other hand, it seems equally evident that other physical causes are the governing forces in their distribution in longitude; but that these are, in fact, mainly climatological, or such as are more or less directly referable to them. The influence of humidity is readily apparent, and so is that of the vegetation, as exhibited in forest and forestless regions in the United States — conditions plainly the result of climatic causes.

It is evident that provinces, faunæ, and floræ, however strongly marked as a whole, have not abruptly defined boundaries, but shade into each other so gradually as to render the determination of their limits from present data but provisional at best, since probably no two species are quite alike in their adaptations, though a certain proportion in a given district coincide more nearly than the others, forming a group characteristic of the region. Through the recognition of such groups, the eastern portion of the North American continent was

[1] Proc. Bost. Soc. Nat. Hist. Vol. X, p. 260.

[2] It is well known that several species of the Canadian fauna, as *Junco hyemalis*, *Zonotrichia leucophrys*, *Pinicola enucleator* (*P.* "*canadensis*"), and others, are found in the higher parts of the Appalachian ranges to their southern termination in Georgia, while *P. enucleator*, *Curvirostra americana* and *Plectrophanes nivalis* occur on the slopes of the snow-crowned mountains of southern Mexico, as well as on the more northern table-lands, where altitude produces the isotherms under which the species are found in the northern and alpine portions of New England, hundreds of miles to the northward.

some time since separated, in a general way, into the Canadian, Alleghanian, and Louisianian, faunæ and floræ, which divisions later special investigations of the subject tend to support whether with regard to the distribution of plants, mammals, birds, reptiles, or insects.[1] The several avi-faunæ already definitely recognized seem to be characterized in part by the abundant occurrence, in the breeding season, of the following species: Commencing with Florida, the southern portion of it is clearly West Indian in its affinities, through the presence especially of *Quiscalus agelæus, Tyrannus dominicensis, Coccygus minor, Crotophaga rugirostris, Zenæda amabilis, Asturina nitida, Polyborus tharus, Phenicopterus ruber*, etc. The Louisianian by *Peucæa æstivalis, Cyanospiza ciris, Pyranga æstiva, Antrostomus carolinensis, Quiscalus major, Collyrio ludovicianus, Chamæpelia passerina, Elanus leucurus, Ictinia mississippiensis*, etc. The Alleghanian has but few if any species that do not occur either in the Louisianian or Canadian, though differing widely from either in the association of the species. Many that breed abundantly here, but do not in the Louisianian, breed also in the Canadian, while many others that breed here breed also in the Louisianian, but not in the Canadian. Of the first class we may mention *Turdus migratorius, Turdus fuscescens, Mniotilta varia, Hirundo (Tachycineta) bicolor, Hirundo (Petrochelidon) lunifrons, Quiscalus versicolor, Tringoides macularius, Pipilo erythrophthalmus, Chordeiles popetue*, etc.; of the second: *Icterus spurius, Icteria virens, Dendrœca discolor* (?), *Coturniculus passerinus, Euspiza americana, Ortyx virginiana*, etc. Of the Canadian, *Turdus Pallasi, T. Swainsoni*, a large proportion of the *Dendrœcæ, Spizella monticola, Junco hyemalis, Passerella iliaca, Zonotrichia leucophrys, Z. albicollis, Scolecophagus ferrugineus, Parus hudsonicus, Picoides arcticus, Astur atricapillus, Tetrao (Canace) canadensis*, and a considerable list of others. Of the Hudsonian or Sub-arctic, *Lagopus albus, Archibuteo lagopus, Colymbus septentrionalis, Somateria mollissima, S. spectabilis, Histrionicus torquatus, Graculus dilophus*, and several others, mostly aquatic and marine. A few others, chiefly circumpolar marine birds, will characterize a still more northern or the Arctic fauna. From the above it will be seen that the Alleghanian fauna differs from the others in having few if any species peculiarly its own, forming, as it were, transitional ground between the two adjoining it. It is here, too, — but perhaps only because the region is better known,— that as we advance from the south northward, species are seen so conspicuously to fade out one after another at frequent intervals throughout the whole area, though in greater numbers relatively near its boundaries.

From the facts at command, the division between the West Indian fauna in Florida and the Louisianian seems to coincide nearly with the line of mean temperature of 79° F. for the months of May, June, and July;[2] between the Louisianian and Alleghanian, nearly with that of 72° for the same time; between the Alleghanian and Canadian, nearly with that of 65°; between the Canadian and Hudsonian or Sub-Arctic, nearly with that of 56°. The line of 72° for the northern limit of the Louisianian fauna embraces the low lands of the coast as far as Cape May, and perhaps farther north, but, running a few miles only into the interior,

[1] Commencing our investigations without reference to what had been done previously, and with the question, "Do physical causes really influence the distribution of animals and plants?" our study thus far but corroborates the general views on this subject already advanced by others (see especially Prof. Verrill, on the causes that influence the distribution of birds in latitude. l. c.). The results of a detailed study of the available data on the distribution of American birds we hope to be able to present at no distant day.

[2] We prefer to take the months of May, June, and July rather than April, May, and June, since but few species, comparatively, breed so early as April, especially north of the Louisianian fauna, while the breeding season with many species, and especially at the northward, continues through July, and in some species still later.

sweeps rapidly southwards, gradually approaching the Appalachian mountains in Virginia, but keeping east of them, passes down around them in Georgia; then turning abruptly northwards it follows near their western base, crossing the Ohio not far from Cincinnati; thence running westerly passes near Springfield, Ill., and, rising rapidly northwards as it approaches the Mississippi, crosses that river near Rock Island; thence in its westerly course it makes a considerable and sudden bend to the south, rising north again in approaching the Missouri, and continuing on apparently just north of this river till it reaches the sterile plains. The line of 65° for the northern limit of the Alleghanian, nearly or quite coincides with the limit assigned it by Prof. Verrill.

Besides the shading together of contiguous faunæ already referred to, there is a straggling of representatives of certain species properly characteristic of one fauna through the next one north, especially noticeable in several species of the Louisianian fauna, which not unfrequently reach New York, and occasionally Massachusetts. There is also a shading in together of the Eastern and Western Provinces through the occurrence of several western species on the prairies, which in general form their eastern limit, and a similar extension westward, especially up the wooded valleys of the rivers, of species properly eastern.

I. Western Iowa.

Climatologically the prairies differ considerably from the States along the eastern sea-board, on account of the adjoining wooded districts, and still more, their interior location. This difference is most manifest in the more excessive extremes of heat and cold, moisture and drought, and the greater prevalence of high winds. The summer, as a whole, is hotter, or more tropical,[1] and the winter colder, though apparently the thermometric range is not much greater than in the same latitudes eastwards.[2] The strong winds, which sometimes prevail with great violence for days together, cannot but have some influence in determining the particular character of the flora and fauna. In summer they render the great heat more endurable, but in winter add greatly to the rigor of the climate, and at times render a journey across even a comparatively narrow expanse of prairie extremely hazardous for either man or beast. In addition to its ameliorating and intensifying effects, its mechanical force alone is evidently not wholly without effect, especially upon sensitive species.

Iowa being, as is well known, eminently a prairie State, we should expect, from the scarcity of forest growth, an avi-fauna somewhat different from what exists in well-wooded regions otherwise similar. And this we find to be the case; the most marked differences being the general scarcity of birds of all kinds,[3] the relative abundance of a few prairie-

[1] The past summer I found in July and August the temperature for weeks together, during midday, ranging from 84° to 96° F. I was at the same time assured that this was not an unusual season.

[2] I am aware that this statement is somewhat at variance with high authority on the Climatology of the United States. Mr. Blodgett, in remarking on the general character of the climate east of the Rocky Mountains, observes: "The early distinction between the Atlantic States and the Mississippi Valley has been quite dropped, as the progress of observation has shown them to be essentially the same, or *to differ in unimportant particulars*. It is difficult to designate any important fact entitling them to separate classification; they are alike subject to great extremes and to the same extremes, they both have strongly marked continental features at some seasons, and decided tropical features at others, and these influence the whole district similarly, without showing any line of separation." L. Blodgett, in *Climatology of the United States* (1857), p. 126. Compared with the wide climatic differences presented by the middle and western portions of our continent the difference admitted may seem unimportant, in a general review of the climates of a continent, yet they are of a sufficient degree to become more or less prominent modifying influences of faunæ and floræ.

[3] The following extract from an entry in my journal under date of August 20, 1867, after spending three days in the narrow belt of grand old timber skirting the Middle Coon, a few miles above Redfield (Dallas Co.), quietly botanizing, but

loving species, and a corresponding scarcity of those whose favorite haunts are the forest. In its western part there are still considerable tracts quite primitive in character, while in no portion of the western half has man greatly modified its fauna and flora. A change, however, has commenced; and, with these broad prairies, almost inexhaustible in fertility, inviting the industry of the East, twenty years, judging from the rapidity of the transformation now in progress in the eastern part of the State, and which has already swept over Northern Illinois, will see these virgin tracts converted into cultivated farms, with orchards, clumps of sheltering trees, and wind-breaking hedges; the wild weeds and grasses supplanted by cultivated and intruding species, with hardly less positive changes in the animals. At present, as the really characteristic birds of the region, we would enumerate the Horned Lark (*Eremophila alpestris = E. cornuta* Boie), the Lark Finch (*Chondestes grammaca* Bon.), the Meadow Lark (*Sturnella magna* Sw.[1]), the Yellow-winged, Savannah, and Black-throated Sparrows (*Coturniculus passerinus* Bon., *Passerculus savanna* Bon., *Euspiza americana* Bon.), the Prairie Hen (*Cupidonia cupido* Baird), and, in a less degree, the Sand-hill Crane, (*Grus canadensis* Temm.), and Field Plover (*Actiturus Bartramius* Bon.) Also, as characteristic features, the scarcity of the Robin (*Turdus migratorius* L.), the Blue Bird (*Sialia sialis* Bd.), the Barn Swallow (*Hirundo horreorum* Bart.), Chipping and Song Sparrows (*Spizella socialis* Bon., *Melospiza melodia* Bd.), other Sparrows and the common Crow (*Corvus americanus* Aud.)

In explanation of the following list I may add that Boonesboro, in Boone Co., near the centre of the State, where I spent from July 3d to July 12th, was my first point of observation. Here six days were passed entirely in the broad timber belt which skirts the Des Moines River, in the deep, heavily wooded and deeply shaded ravine formed by Pole Cat Creek, which gave me early in the season a favorable opportunity to become somewhat familiar with the forest haunting species. July 13th I passed on nearly a hundred miles westward to Denison, on the Boyer River, and distant from the Missouri, in a direct line, but little more than thirty miles. Here my field of observation embraced both timber and prairie, and during the week passed in it I became quite familiar with the species of the prairie. July 20th I joined my friend Mr. O. H. St. John, who was prosecuting the geological survey of the State, and with him, during the following two months, traversed seven counties (Crawford, Sac, Greene, Dallas, Guthrie, Audubon, and Caroll), crossing several of them repeatedly and in different directions. Camping wherever night found us, and spending considerable time in the narrow belts of timber bordering the three Coon Rivers (North, Middle, and South), as well as on the prairies, my opportunities for observation could scarcely have been more favorable.[2]

with an eye to the feathered tribes, will serve to illustrate the scarcity of bird-life in the forest. After expressing my surprise at the scarcity of birds seen under the most favorable circumstances, I add: "Two or three species of Woodpeckers, (only the Red Head, *Melanerpes erythrocephalus*, at all common), a few Blue Jays and two or three Wood Pewees (*Contopus virens*), a few families of Chickadees, (*Parus atricapillus*), two Robins, as many Baltimores (*Icterus Baltimore*), and a very few Warbling Vireos, a few Cedar Birds, King Birds, Yellow Birds, (*Chrysomitris tristis*), Swallow-tailed Hawks, and Turkey Buzzards flying over, and a Kingfisher and two species of Sandpipers along the river, comprise all either seen or heard. This is in marked contrast with similar situations at this season in New England, where, instead of silence almost for hours together, numbers of species would be constantly heard, and many times each day would considerable parties of Warblers, Vireos, Titmice, Nuthatches, Woodpeckers, and other species, varied but harmonious companies, have passed our camp." About twenty species were actually noted during these three days, but only about half a dozen could be considered common, while nearly half were seen but once or twice. On the wild prairies I often noted a similar scarcity — long rides with hardly a bird to notice to relieve the tedium; and generally their feathered inhabitants were mainly of less than half a dozen species.

[1] See remarks on this species beyond.

[2] For this I cannot too fully express the obligations I am under to Dr. C. A. White, Director of the Iowa State Geo-

Of the one hundred and eight or ten species observed, at least one hundred may be set down as undoubtedly breeding in the State, the others being observed only after the autumnal migration had set in. This number indicates that the avi-fauna is as varied, though less numerous in point of individuals, as at most other points to the eastward away from the seacoast, since the whole number of species that breed regularly in Massachusetts does not exceed one hundred and thirty, including several properly marine species, while fully one fifth, or twenty per cent., are too fewly represented to be considered characteristic. This is also about the number given by Dr. Coues and D. W. Prentiss for the District of Columbia.[1]

Turdidæ.[2]

1. *Turdus migratorius* Linn. Robin. Nowhere very common. Seen chiefly along the skirts of the timber, in which it is forced to breed, the prairies being, of course, naturally treeless, and the country too recently settled to possess orchards. West of Boonesboro, during a period of over two months, I saw not more than fifty individuals altogether. Said to be pretty common in spring.

2. *Turdus mustelinus* Gmel. Wood Thrush. Found very abundant along the Des Moines River, near Boonesboro, in the first half of July, where the heavy timber and deeply shaded ravines form just its favorite haunts.

3. *Turdus fuscescens* Steph. Wilson's Thrush. With the preceding; equally common and almost as retiring.

4. *Seiurus aurocapillus* Sw. Golden-crowned Thrush. With Nos. 2 and 3 at Boonesboro. Rather common, but, unlike its usual habit, as shy and difficult to procure as either of its above-mentioned associates.

5. *Seiurus noveboracensis* Nutt. Water Thrush. Several pairs seen at the Boonesboro locality, and several specimens taken. Like each of the preceding, it undoubtedly breeds there.

6. *Galeoscoptes carolinensis* Cab. Cat Bird. Occasionally seen in the thickets, and even in quite heavy timber. In some localities very rare, and generally much less common than at the East.

7. *Harporhynchus rufus* Cab. Brown Thrush. Quite common about the timber bordering the rivers, and at Boonesboro often seen in its darkest and densest parts. Saw here a female feeding a nearly full-grown Cow Bird (*Molothrus pecoris* Sw.)

Saxicolidæ.

8. *Sialia sialis* Bd. Blue Bird. Not frequent, and seen only in the vicinity of the timber.

Paridæ.

9. *Parus atricapillus* Linn. Black-capped Titmouse. The most common woodland bird.

logical Survey, and to Mr. St. John, his able assistant on the Survey.

1 "List of Birds ascertained to inhabit the District of Columbia," etc. Smithsonian Report, 1861, pp. 399, 421.

2 In the following lists the "*Arrangement of Families of Birds*, adopted provisionally by the Smithsonian Institution," is generally followed. We deem it as a whole, one of the best arrangements yet prepared, and in the removal of the birds of prey from the high position they have, in most systems, always, but most unwarrantably held, to a position more in accordance with their real zoölogical rank, as making a decided advance towards the natural system. We adopt it, of course, but provisionally, and with but slight modifications, chiefly in regarding the *Phalaropodidæ* and the *Podicipidæ* as sub-families respectively of *Scolopacidæ* and *Colymbidæ*. It seems to me there is indisputable evidence that the *Fringillidæ* are the

Certhiadæ.

10. *Certhia familiaris* Linn.[1] Brown Creeper. Noticed chiefly towards autumn, though doubtless resident.

Sittidæ.

11. *Sitta carolinensis* Gmel. White-bellied Nuthatch. Common in the groves.

Troglodytidæ.

12. *Troglodytes ædon* Vieill. House Wren. Common about the settlements.

13. *Troglodytes hyemalis* Vieill. Winter Wren. A Wren was seen several times in the timber near Denison and Boonesboro, presumed to be this species. In every case it escaped capture.

Motacillidæ.

14. *Anthus ludovicianus* Licht. Tit Lark. Seen at New Jefferson, Sept. 18th to 22d, in considerable numbers, running about in loose flocks over the furrows of new breakings. Apparently had just arrived from its breeding quarters farther north; none having been seen previously.

Sylvicolidæ.

15. *Geothlypis trichas* Cab. Maryland Yellow-throat. Not uncommon in bush patches and in low grounds at the edges of timber.

16. *Icteria virens* Bd. (*I. viridis* Bon.) Yellow-breasted Chat. Apparently rare. A pair were obtained at Denison, and the species was once or twice noticed elsewhere.

17. *Helminthophaga peregrina* Cab. Tennessee Warbler. Not uncommon about Denison, in the low groves of bur and other oaks.

18. *Dendrœca cærulea* Baird. Blue Warbler. Quite common at Boonesboro, keeping chiefly in the tops of the high trees, and was the only woodland *Dendrœca* observed there.

19. *Dendrœca æstiva* Bd. Yellow Warbler. Occasionally seen about the osage orange and white willow hedges, and the cottonwood groves planted about the farms in the more settled districts, and also about the borders of the timber. This and *D. cærulea* were the only species of the genus observed.

20. *Setophaga ruticilla* Sw. Redstart. Perhaps breeds, but was not observed till the first week in September, when it became quite common. At this time other species of the family were now and then noticed, but under circumstances that prevented their capture. They were probably species that breed beyond the limits of the State.

Hirundinidæ.

21. *Hirundo horreorum* Bart. Barn Swallow. Not generally common. Sometimes none

highest family among birds; and that the *Columbidæ* are, in structural rank, decidedly above the highest forms of the rapacious birds.

[1] I am unable to detect so great differences between average specimens of *C. americana* Bon. from Massachusetts and several skins of *C. familiaris* Linn. from Switzerland (in Mus. of Comp. Zoöl.), as a large series of Massachusetts specimens usually present among themselves. The same may be said in respect to *Eremophila* "*cornuta*" and *E. alpestris*; *Pinicola* "*canadensis*" and *P. enucleator*; *Falco* "*anatum*," and *F. peregrinus*; *Aquila* "*canadensis*," and *A. Chrysaetos*; *Otus* "*Wilsonianus*," and *O. vulgaris*; *Brachyotus* "*Cassinii*," and *B. palustris*, and in several other species in which the American representatives have been supposed by Bonaparte, or Cabanis, or some other authority, to be different from the European. I am indebted to the Museum of Comparative Zoölogy for the opportunity of making comparisons of specimens in these and other cases from the two continents.

seen on our journeys for long intervals. In some sections persons who had resided there for years claimed never to have seen them.

22. *Petrochelidon lunifrons* Bd. (*Hirundo lunifrons* Say.) Cliff Swallow. Often seen flying about over the prairies. The older settlers in Dallas County told me it made its first appearance there three years before, when a colony settled in Redfield, nesting under the eaves of a large sandstone store. This season there were several large colonies in the same vicinity, resorting to the eaves of barns for nesting sites.

23. *Tachycineta bicolor* Cab. (*Hirundo bicolor* Vieill.) White-bellied Swallow. Seen a few times, chiefly towards autumn, flying over the prairies; on several occasions they occurred in great numbers.

24. *Progne subis* Bd. (*P. purpurea* Boie.) Purple Martin. Everywhere common; one of the most abundant of the Hirundines in the breeding season. Said to have been as common when the country was first settled as now. It is a universal favorite, and about almost every house boxes are provided for their accommodation, which they readily occupy as nesting-places in preference to the hollow trees of the woodlands.

25. *Cotyle riparia* Boie. Bank Swallow. Common.

VIREONIDÆ.

26. *Vireosylvia gilva* Bon. Warbling Vireo. Observed occasionally in the timber, but not common. No other species of Vireo noticed, though doubtless several others occur.

AMPELIDÆ.

27. *Ampelis cedrorum* Bd. Cedar Bird. Not very unfrequent.

LANIIDÆ.

28. *Collurio ludovicianus* Bd. Loggerhead Shrike. Not common. Observed but a few times.

TANAGRIDÆ.

29. *Pyranga rubra* Vieill. Scarlet Tanager. Quite common in the timber skirting the rivers, particularly about Boonesboro.

FRINGILLIDÆ.

30. *Chrysomitris tristis* Bon. Yellow Bird. Rather frequent.

31. *Passerculus savanna* Bon. Savannah Sparrow. Rather common on the moister parts of the prairies, and about the grassy ponds or "sloughs."

32. *Poocætes gramineus* Bd. Grass Finch. Now and then seen on the prairies, but not apparently abundant.

33. *Coturniculus passerinus* Bon. Yellow-winged Sparrow. Common. One of the few birds seen far from cultivation when crossing wide stretches of prairie.

34. *Coturniculus Henslowi* Bon. Henslow's Sparrow. Less common than the preceding, frequenting the same situations.

35. *Chondestes grammaca* Bon. Lark Finch. Not abundant, yet at times rather frequently met with. A true prairie bird, as often seen far out on the wild prairie as elsewhere.

36. *Spizella pusilla* Bon. Wood Sparrow. Not common. Observed about thickets at the edges of the prairies.

37. *Spizella socialis* Bon. Chipping Sparrow. Not common nor generally diffused. Observed but a few times, and always about the settlements. Will doubtless multiply rapidly with the increase of cultivated trees and shrubbery, incident to the rapidly increasing population.

38. *Melospiza melodia* Bd. Song Sparrow. Not common. Scarcely observed during the summer; seen near Redfield in September, along the fences of cultivated fields, in considerable numbers. The comparative scarcity of this species was particularly noticed in other localities at the West. (See the following list.)

39. *Euspiza americana* Bon. Black-throated Sparrow. One of the most abundant birds of this section. Eminently a prairie species, and one of the few inhabitants of the wide open stretches.

40. *Hedymeles ludoviciana* Cab. (*Guiraca ludoviciana* Sw.) Rose-breasted Grosbeak. Frequent in the groves along the streams.

41. *Pipilo erythrophthalmus* Vieill. Towhe. Common about the timber, and often seen in its thickest parts.

ALAUDIDÆ.

42. *Eremophila alpestris.* (*E. cornuta* Boie.) Horned Lark. Common on the prairies everywhere, where it is one of the most conspicuous and characteristic birds.

ICTERIDÆ.

43. *Dolichonyx oryzivorus* Sw. Bobolink. Not generally diffused. Seen at intervals, generally few in numbers, and chiefly late in the season. Seen at New Jefferson as late as September 22d, — much later than I ever observed it in Massachusetts.

44. *Molothrus pecoris* Sw. Cow Bird. Not numerous. Its relative scarcity is no doubt the result of the fewness of the small birds, on which, as foster-parents, its existence depends. Here, sometimes at least (see ante), it is reared by the Brown Thrush, a bird larger than itself, and a larger species than I ever knew it to select for foster-parent at the East.

45. *Agelæus phœniceus* Vieill. Red-winged Blackbird. Common. Extremely abundant in the cultivated districts after the breeding season, resorting then, in company with the Purple Grakle (*Quiscalus versicolor* Vieill.) first to the wheat-fields and later to the fields of corn.

46. *Xanthocephalus icterocephalus* Bon. Yellow-headed Blackbird. A few were seen the first week in July, about the grassy ponds near Boonesboro. Said to breed in great numbers to the northwards and eastwards, in the grassy marshes of the Skunk River country.

47. *Sturnella magna* Sw. (*Sturnella neglecta* Aud.) Meadow Lark. Very abundant; one of the most numerous and conspicuous of the prairie birds. Very different from the eastern Meadow Lark in its song, but scarcely presents other tangible differences.[1] At the little

[1] "As a general rule where the dark brown in *S. magna* margins the shaft of the feather and sends off angular dentations towards the exterior, in *S. neglecta* it is thrown into separate narrow transverse bands going entirely across, and not connected by brown along the shafts. This is most particularly the case on the outer webs of the tertials and of the middle tail feathers, and to a less marked extent on the inner webs." Prof. S. F. BAIRD, *Gen. Rep. on North Am. Birds,* (*Vol. IX. P. R. R. Reports*), p. 537. — There is a specimen of *S. magna*, from Massachusetts, in the Museum of Comparative Zoölogy, in which the transverse markings of the "tertials" (inner secondaries), and middle tail feathers are as distinct as in the most typical specimens of *S.* "*neglecta*." Among my Iowa specimens there are again specimens with these bars as much united as is ordinarily the case with *S. magna* in the Atlantic States. There are also specimens from the far west,

village of Denison, where I first noticed it in song, it was particularly common, and half domestic in its habits, preferring apparently the streets and grassy lanes, and the immediate vicinity of the village, to the remoter prairie. Here, wholly unmolested and unsuspicious, it collected its food; and the males, from their accustomed perches on the house-tops, daily warbled their wild songs for hours together. Though in this trait of familiarity differing widely from its eastern representative, it is a difference of habit common to too many species in the newer parts of the West, where the birds are encouraged by man instead of destroyed, to be relied on as a distinctive character. Its song, however, was so new to me I did not at first have the slightest suspicion that its author was the Western Meadow Lark, as I found it to be, the time being between daylight and sunrise, and the individual in question singing from the top of the Court House. It differs from that of the Meadow Lark in the Eastern States, in the notes being louder and wilder, and at the same time more liquid, mellower, and far sweeter. They have a pensiveness and a general character remarkably in harmony with the half-dreary wildness of the primitive prairie, as though the bird had received from its surroundings their peculiar impress; while if less loud their songs would hardly reach their mates above the strong winds that almost constantly sweep over the prairies in the hot months. It differs, too, in the less frequency of the harsh complaining chatter so conspicuous in the Eastern birds, so much so that at first I suspected this to be wholly wanting. My estimate of the value of this difference of song, as an indication of specific diversity, is somewhat modified by the fact that on my journey westward I found already the notes of the Meadow Larks so different in Northern Illinois, as far east as Chicago even, from those of Massachusetts birds, that I could not help remarking the difference, and entered the fact among my notes; the variation, moreover, being towards the Western Iowa type.

48. *Icterus Baltimore* Daud. Baltimore Oriole. Not common, and confined to the timber. A single highly plumaged male was seen in crossing a wide extent of prairie in northern Carrol County, September 18. It was first noticed resting on the weeds in the road just in front of our horses, and on halting it came immediately about the wagon, alighting on the spokes of the wheels and beneath it on the reach. It appeared like a lost bird, exhibiting great satisfaction in our company, and was not readily frightened away, following us for a little distance as we resumed our journey. The incident struck us as quite remarkable. The day being dark and rainy, nothing was visible at this point but the gently rolling grassy prairie stretching on either hand as far as the eye could reach.

49. *Icterus spurius* Bon. Orchard Oriole. Not common. Observed in the same situations as the preceding, and in about the same numbers.

50. *Quiscalus versicolor* Vieill. Purple Grakle. Very abundant in the cultivated districts. By the first of August they had begun to gather in flocks, frequenting the wheat-fields, and afterwards the corn. In Guthrie County, in September, saw them in immense flocks, passing through the air in long trains, and blackening the corn-fields for a large extent whenever they alighted. With them were usually associated a considerable number of the Redwings (*Agelæus phœniceus* Vieill.).

one from California especially, sent by the Smithsonian Institution to the Museum of Comparative Zoölogy, of the same character. Prof. Baird also alludes to specimens from Fort Steilacoom and from California, which, at least one in particular, "agree in every respect with eastern specimens." Hence, the well-marked difference in song seems to be the real, (constant?) distinction between the eastern and western birds.

Corvidæ.

51. *Corvus americanus* Aud. Common Crow. But very few seen

52. *Cyanura cristata* Sw. Blue Jay. Common in the groves, and nearly as unsuspicious as the Black-capped Titmouse.

Tyrannidæ.

53. *Tyrannus carolinensis* Bd. King Bird. Rather common wherever there are trees or groves. Seen as late as September 20, or two weeks later than it usually remains in Massachusetts.

54. *Tyrannus verticalis* Say. Arkansas Flycatcher. At Boonesboro a pair of large Flycatchers were seen in the timber, which I scarcely doubt were of this species. Having no gun with me at the time, I was unable to get them, and did not meet with the species elsewhere.

55. *Myiarchus crinitus* Cab. Great-crested Flycatcher. Common everywhere in the timber.

56. *Sayornis fuscus* Bd. Pewee. Here and there common.

57. *Contopus virens* Cab. Wood Pewee. Common in the timber.

58. *Empidonax minimus* Bd. Least Pewee. Rather common about the timber at Boonesboro.

Alcedinidæ.

59. *Ceryle alcyon* Boie. Kingfisher. Common along the streams.

Caprimulgidæ.

60. *Antrostomus vociferus* Bon. Whip-poor-will. Common. Heard as late as Sept. 20.

61. *Chordeiles popetue* Bd. Night Hawk. Sometimes not seen for a long time, and again met with in abundance. Began to leave the State early in September, but some remained as late as the 20th.

Cypselidæ.

62. *Chætura pelasgia* Steph. Chimney Swift. Common. Breeds in hollow trees. In no instance could I hear of its resorting to chimneys, which in general are poorly adapted to its wants, consisting often either of a joint of stovepipe, or a patent one of cast-iron.

Trochilidæ.

63. *Trochilus colubris* Linn. Ruby-throated Humming Bird. But very few seen.

Cuculidæ.

64. *Coccygus erythrophthalmus* Bon. Black-billed Cuckoo. Several seen; apparently not uncommon.

Picidæ.

65. *Picus villosus* Linn. Hairy Woodpecker. Not uncommon in the timber.

66. *Picus pubescens* Linn. Downy Woodpecker. Quite common.

67. *Sphyrapicus varius* Bd. Yellow-bellied Woodpecker. Very common. Young fully fledged were observed the first week in July. Shot several while engaged perforating

the bark of basswood and other trees; I found spiders, ants, beetles, and "daddy-long-legs" in their stomachs, but no vegetable matter whatever.[1]

68. *Centurus carolinus* Bon. Red-bellied Woodpecker. Rather common.

89. *Melanerpes erythrocephalus* Sw. Red-headed Woodpecker. Abundant in and near the groves.

70. *Colaptes auratus* Sw. Golden-winged Woodpecker. Very common, but, like the rest of the *Picidæ*, was not seen very far from the timber.

STRIGIDÆ.

71. *Syrnium nebulosum* Gray. Barred Owl. Very common; the most abundant of the Owls. Frequently seen in the day-time, while at night the groves were often filled with its strange and varied notes. They often strikingly resembled the "*Who cooks for you all*" attributed by Wilson to the Great Horned Owl, but in whose notes I have as yet failed to trace its resemblance.

72. *Bubo virginianus* Bon. Great Horned Owl. Apparently rare. Only once detected its familiar notes.

73. *Scops asio* Bon. Mottled Owl. Abundant in and near the timber.

FALCONIDÆ.

74. *Tinnunculus sparverius* Vieill. Sparrow Hawk. Common. One of the most numerous species of Hawk. I often saw it catching large grasshoppers, for which purpose it would hover in the air at a height of a hundred feet or more, intently surveying the ground beneath, and on discovering its prey descend rapidly to clutch it, but which very often escaped it. When unsuccessful it would rise but a few yards and hover over the spot to rediscover it, failing in which it soon rose to its former height, to continue its search as before.

75. *Buteo borealis* Vieill.[2] Red-tailed Hawk. Common; chiefly seen in the vicinity of the timber. Shot one that was feeding on a Fox Squirrel (*Sciurus ludovicianus* Custis).

76. *Buteo lineatus* Jard. Red-shouldered Hawk. Occasionally observed towards autumn.

[1] The perforations made in the bark of trees by Woodpeckers, forming transverse rings, and sometimes so numerous as to do serious injury to the trees, have of late been very commonly attributed almost solely to this species, especially at the West, where it is so numerous. That it is, from this habit, often greatly injurious to fruit and other trees is not to be denied; but that this species — now commonly styled the "true Sap-sucker," to whose depredations, it is said, should be assigned the general ill-repute attached to the whole family by most agriculturists — is the sole author of this work, which so often amounts to mischief, there is abundant evidence to disprove. In most parts of Massachusetts, particularly in the Connecticut Valley, this species is so extremely rare that I have never seen more than half a dozen specimens in a year, and oftener none at all, and then always during its migrations; while other expert collectors have searched for it unsuccessfully for years; yet our orchards always present these perforations in profusion, though seldom to an injurious degree; and now and then a forest tree is observed so thoroughly girdled as to be thus destroyed. For this our Spotted Woodpeckers, *Picus pubescens* and *P. villosus*, are chargeable, being in many sections the sole authors of it; they may be, in fact, very often seen engaged in it. I do not, however, suppose their object to be the same as that assigned to the *Sphyrapicus varius* — that of sucking sap or feeding on the inner bark — neither do I suppose the peculiar anatomical modifications presented by the *Sphyrapici* specially contrived to adapt them to a "xylophagous" diet. In Vermont, where I have observed *S. varius* in abundance, no trees were so extensively perforated as the hemlock (*Abies canadensis* Mich.), a resinous, heavy barked tree. In dozens of specimens whose stomachs I have examined, I have in but a single instance found any quantity of cambrium, and always more or less insects; chiefly ants, beetles, and spiders, but rarely or never wood-boring larvæ.

[2] A considerable variety of plumage in respect to color was observed, from individuals very dark to the types more common in the Eastern States; these different varieties representing several of the supposed valid, but probably merely nominal species described by Cassin and others from the middle and western parts of the continent. If we admit more than the well-marked and sufficiently distinct *B. borealis*, *B. lineatus*, and *B. pennsylvanicus*, and possibly one other, we may, as Dr.

77. *Circus hudsonius* Vieill. Marsh Hawk. Seen almost daily, flying low and rapidly over the prairies. The only Hawk seen habitually on the open prairie.

78. *Nauclerus furcatus* Vigors. Swallow-tailed Hawk. Common. Often seen in considerable numbers, and generally over or near the timber skirting the streams. At Denison, in the timber of the Boyer River, they were very common and nesting; the nests being placed on horizontal branches, at some distance from the trunk. By the middle of July the young had not flown. With a peculiarly graceful, swallow-like flight this beautiful bird was seen not infrequently skimming over the prairies, singly or two or three in company, eagerly searching for their reptile food.

VULTURIDÆ.

79. *Cathartes aura* Ill.[1] Turkey Buzzard. Common, and generally distributed. On several occasions I saw them collected about the carcass of a dead animal in considerable numbers. At Panora I once saw them congregated in hundreds, attracted by two dead pigs. Frequently observed them resting on the fences and wheat stacks, in very hot days opening their wings to catch the breeze, the very pictures of indolence. In southern Guthrie County is a locality known as "Buzzards' Roost," it is said from the number of these birds that resort there

COLUMBIDÆ.

80. *Zenædura carolinensis* Bon. Mourning Dove. Very abundant, and almost domestic.

MELEAGRIDIDÆ.

81. *Meleagris gallopavo* Linn. Wild Turkey. Said to have been rather common about the groves when the country was first settled, and to exist in small numbers still.

TETRAONIDÆ.

82. *Cupidonia cupido* Bd. Prairie Hen. Generally abundant. This season rather scarce; owing to the extreme wetness of the spring and early summer few young were raised. Rarely any but old birds seen, which were shy and hard to get. Exclusively a prairie bird, as its name indicates. At Boonesboro it was said to have the singular habit,

Bryant has remarked (Proc. Bost. Soc. Nat. Hist. Vol. VII, 107), as well admit twenty, or extend the number almost indefinitely. The species of *Buteo* already admitted by different authors, for temperate North America, numbering twelve to fifteen, is an altogether improbable number, considered in reference to the evidence furnished on this point by what is known of the general distribution of these birds; while in the additional light of the well-known variability of its representative of the Eastern Continent, *Buteo vulgaris*, it becomes quite incredible. Judging from the whole number of undoubted species of this family now known, and their relative distribution in different countries, we have apparently no good reason to expect more than the three or four well-marked ones of this genus, which we certainly have, as enumerated above. Again, the wide range of individual variation, especially in color, which eminently marks all the *Falconidæ*, renders the characters assigned for many of our *Buteos* of little weight.

[1] While no character has been adduced showing satisfactorily specific diversity between *C. aura* Ill. and *C. atratus* Less., of North America, and their supposed distinct allies, *C. jota* and *C. braziliensis*, of South America, there is a correspondence in their relative distribution in the higher latitudes on each side of the equator which seems to strongly indicate their identity. But, in fact, we are now able to trace both of our North American species across the tropics. In North America the *C. aura* Ill. exceeds the range northwards of *C. atratus* Less. by about twelve degrees of latitude, *C. aura* reaching in summer, in the interior, nearly or quite to the 55th parallel, while *C. atratus* has not been traced above the 42d. At the south *C. aura* extends in summer to the Falkland Islands and the southern extremity of the southern continent, (Lat. 52° to 54° south), while *C. atratus* has not been reported below the 40th or 41st parallel. The smaller size of specimens from Brazil, compared with those of the United States, which has been dwelt on as the chief distinction, is only what we should expect from what seems a general law of size among birds — a diminution with the decrease of latitude and increase of temperature in species having a wide range in latitude, and which hundreds of species, in both hemispheres, exemplify.

for a bird of this family, of alighting on the telegraph wires in autumn, sometimes in great numbers. This was related to me by several different persons, whose veracity I saw no reason to doubt.

83. *Bonasa umbellus* Steph. Ruffed Grouse. Common in the groves.

PERDICIDÆ.

84. *Ortyx virginianus* Bon. Quail. Very common.

CHARADRIIDÆ.

85. *Charadrius virginicus* Borck. Golden Plover. Not seen till September 18th, when it became common.

86. *Ægialitis vociferus* Cass. Killdeer Plover. Common throughout the summer.

87. *Ægialeus semipalmatus* Cab. Observed about Jefferson in September.

SCOLOPACIDÆ.

88. *Philohela minor* Gray. Woodcock. Common.

89. *Gallinago Wilsonii* Bon. Wilson's Snipe. Not seen till the 10th of September, but very abundant during the weeks following.

90. *Actodromas minutilla* Coues. Least Sandpiper. Observed along the rivers early in August and later.

91. *Actodromas maculata* Cass. Pectoral Sandpiper. Abundant in September.

92. *Ereunetes pusillus* Cass. Abundant at Jefferson in September.

93. *Tringoides macularius* Gray. Spotted Sandpiper. Not uncommon along the streams.

94. *Actiturus Bartramius* Bon. Field Plover. One of the common prairie birds, and quite unsuspicious.

95. *Numenius longirostris* Wils. Long-billed Curlew. Common in spring, and doubtless breeds about the marshes.

96. *Steganopus Wilsoni* Coues. (*Phalaropus Wilsoni* Sab.) Observed in August and September.

GRUIDÆ.

97. *Grus canadensis* Temm. Sand-hill Crane. Said to be numerous in spring and fall, and retiring only to the more unsettled districts to breed. Saw several in August stalking about on an uninhabited prairie, and often in September, flying over at great heights. Said to breed abundantly in the marshes of the Skunk River country, near the middle of the State.

ARDEIDÆ.

98. *Ardea herodias* Linn. Great Blue Heron. Rather common. At night we frequently started it from its feeding-grounds when camped near streams.

99. *Botaurus lentiginosus* Steph. Bittern. Common about the marshes.

100. *Butorides virescens* Bon. Green Heron. Common.

RALLIDÆ.

101. *Rallus virginianus* Linn., and perhaps one or two other species of this family were observed in crossing marshy tracts of prairie, but none were collected.

Anatidæ.

102. *Anas boschas* Linn. Mallard. Occasionally seen; doubtless breeds in the State.

103. *Anas obscura* Gmel. Black Duck. Not uncommon in summer along the rivers and in grassy ponds.

104. *Nettion carolinensis* Bd. Green-winged Teal. Seen about ponds in August.

105. *Querquedula discors* Steph. Blue-winged Teal. Observed with the preceding.

106. *Aix sponsa* Boie. Wood Duck. Quite common.

In spring and fall, geese, probably several species, and several other species of ducks are reported to abound. I was also told that geese (probably *Bernicla canadensis* Boie) breed in considerable numbers in some of the grassy ponds in this part of the State.

Laridæ.

107. *Hydrochelidon fissipes* Gray. Sooty Tern. Seen in great numbers July 20, about Wall Lake, in Sac County. The young had already flown, and were accompanying their parents. Not seen elsewhere in our travels in this State.

Colymbidæ.

108. *Podilymbus podiceps* Lawr. Carolina Grebe. Seen in August in company with the ducks above mentioned.

II. Northern Illinois.

As my observations on the birds of Northern Illinois were made chiefly at two localities one hundred miles apart, with an interval of time between, in which there was a considerable change in the species represented, in consequence of the change in the season, I have thought it best to give them under two distinct lists. The first of these lists, that of Ogle County,[1] embraces only birds observed during the last three weeks of June, and consequently only those breeding or fully settled for the summer.[2] This list includes probably more than two thirds of the species that breed in the county, and nearly all that, from their number of representatives, are characteristic of the district. The second list, that of Cook County, though still less complete, and, from the earlier period of the observations (last half of May), affording less valuable data on distribution, many of the species noticed being on their passage northwards, is believed to furnish several points of interest. On comparing these with lists for different localities in the Atlantic States for the corresponding period, considerable differences will be noticed; especially in the comparative abundance of certain species that are rarely or never met with on the Atlantic slope, under the same latitude. Conspicuous among the first of these are *Perissoglossa tigrina*, *Wilsonia pusilla* and *W. mitrata*, *Helminthophaga peregrina*, *Vireo Philadelphicus*, *Euspiza americana*, *Melospiza Lincolnii*, *Centurus carolinus*, and *Phalaropus Wilsoni;* others more or less common here that are almost never met with in the east are *Collurio excubitoroides*, *Chondestes grammaca*, and *Xanthocephalus icterocephalus*, and also, in the breeding season, *Eremophila alpestris*. The occurrence of the latter constitutes the more positive differences in the two regions, and marks the change in the avi-fauna in passing from the primitively wooded districts to the prairies.

[1] Ogle County is on Rock River, about one hundred miles nearly due west from Chicago. Cook County borders on Lake Michigan, and embraces Chicago within its limits. Evanston was the principal point of observation in this county.

[2] We spent a few weeks here also in October; but the few notes made at that time, which are incorporated with the others, have the date of the observation distinctly stated.

The Ogle County list shows that but a small number of *Sylvicolidæ* breed there in any numbers, as my field of observation embraced the wide timber belt bordering Rock River, as well as the adjoining prairie. I was also much surprised not to meet here with *Turdus fuscescens*. Mr. Wm. Blackburn, an intelligent taxidermist of Rockford (Ill.), who through a residence of many years and his profession has apparently become very familiar with the birds of this vicinity, informed me that the warblers, even in the migrating season, are never abundant, and that but four or five species (*Dendrœca virens, D. æstiva, D. castanea, D. pennsylvanica, Setophaga ruticilla*) were really common. On the other hand, the "groves" or forests skirting Lake Michigan, in Cooke County, seemed to abound with them to a remarkable degree. They are perhaps more easily observed here from the fact that, through the retarding influence exerted by the lake on the development of vegetation in spring, they arrive before the buds on the trees are much swollen, and there is nothing to conceal them. Again, the lake itself, and the peculiar distribution of the forests of the contiguous region, may, and undoubtedly do, tend to deflect their course somewhat, and thus crowd them together in their passage along the western side of Lake Michigan to the forests of northern Wisconsin and the adjacent wooded regions further to the north. Dr. Hoy has already called attention to the fact of the great abundance at Racine, one hundred miles north of Evanston, of all the migratory birds, — that point, he observes, being apparently a kind of rendezvous they make in their migrations.[1]

In the Cook County list the writer discusses at some length a question previously raised by him respecting the validity of certain so-called species of North American Thrushes,[2] and gives his reasons for considering that there are but three species of the group in question, instead of seven, the number given by Prof. Baird, in his *Review of American Birds*.[3]

A. — *Ogle County*.

TURDIDÆ.

1. *Turdus migratorius* Linn. Frequent, but not abundant.
2. *Turdus mustelinus* Gmel. Common.

No specimens of *T. fuscescens* Steph. were seen, though places apparently perfectly adapted to them were not wanting.

3. *Seiurus aurocapillus* Swain. Not uncommon.
4. *Galeoscoptes carolinensis* Cab. Common.
5. *Harporhynchus rufus* Cab. Common.

SITTIDÆ.

6. *Sitta carolinensis* Gmel. Common.

PARIDÆ.

7. *Parus atricapillus* Linn. Very common.
8. *Lophophanes bicolor* Bon. Said to occur. Probably not common. None observed.

[1] "This city (Racine, Wis.) is situated at the extreme southern point of the heavy timbered district, where the great prairies approach near the lake from the northwest, and is a remarkably favorable position for ornithological investigation. It would appear that this is a grand point, a kind of rendezvous, that birds make during their migrations." Dr. P. R. HOY'S "Notes on the Birds of Wisconsin." Proc. Phil. Acad. Nat. Sc., VI, (1853).

[2] See Proceed. Essex Inst. Vol. IV, p. 56, (1864).

[3] Review of Am. Birds, Part I, p. 12, *et seq.*, (1864).

Troglodytidæ.

9. *Troglodytes ædon* Vieill. Abundant.

Sylvicolidæ.

10. *Dendrœca pennsylvanica* Bd. Frequently seen, and was undoubtedly breeding.
11. *Dendrœca æstiva* Bd. Rather common.
12. *Helminthophaga* sp. A species of the genus, probably either *peregrina* or *ruficapilla*, was observed.
13. *Geothlypis trichas* Cab. Common, in its usual haunts.
14. *Icteria virens* Bd. (*Icteria viridis* Bon.) Several noticed, but apparently not very common.

Among other species of this family that probably breed here is *Dendrœca virens* Bd., though it is not probably common in summer.

Hirundinidæ.

15. *Hirundo horreorum* Barton. Abundant.
16. *Petrochelidon lunifrons* Bd. (*Hirundo lunifrons* Say). Here and there a colony.
17. *Cotyle riparia* Boie. Nesting abundantly in the banks of Rock River. Young nearly full-fledged June 24.
18. *Progne subis* Bd. (*P. purpurea* Boie.) Common.

Vireonidæ.

19. *Vireosylvia olivacea* Bon. Common.
20. *Vireosylvia gilva* Cass. Common.

Probably also both *Vireosylvia Philadelphica* Cass., and *Vireo noveboracensis* Bon. occur at this season sparingly.

Ampelidæ.

21. *Ampelis cedrorum* Bd. Rather common.

Laniidæ.

22. *Collurio excubitoroides* Bd. Somewhat common. Young fully fledged June 20th, and accompanying their parents.

Tanagridæ.

23. *Pyranga rubra* Vieill. Common.
24. *Pyranga æstiva* Vieill. Said to occur, but is probably rare. Not observed.

Fringillidæ.

25. *Chrysomitris tristis* Bon. Abundant.
26. *Passerculus savanna* Bon. Not apparently common in summer. Frequent in autumn.
27. *Poocætes gramineus* Bd. Abundant.
28. *Coturniculus passerinus* Bon. Apparently not common.
29. *Chondestes grammaca* Bon. Rather common. Seen frequently flitting along the roads.
30. *Spizella pusilla* Bon. Rather common.
31. *Spizella socialis* Bon. Scarce. But a single pair noticed.
32. *Melospiza melodia* Bd. Very much less common than in Massachusetts. But very few observed.

M. palustris Bd., was very abundant October first, as were also *M. Lincolnii* Bd., *Zonotrichia albicollis* Bon., and *Z. leucophrys* Sw.

33. *Euspiza americana* Bon. Exceedingly abundant; the most numerous species of the family. Found nesting in grass (nest a foot and a half from the ground), with fresh-laid eggs, June 18.

34. *Hedymeles ludoviciana* Cab. (*Guiraca ludoviciana* Sw.) Apparently common.

35. *Cyanospiza cyanea* Bd. Very common. Found its nests, with nearly fresh eggs, June 24.

36. *Pipilo erythrophthalmus* Vieill. Very common. Quite abundant as late as Oct. 12th

ALAUDIDÆ.

37. *Eremophila alpestris* (*E. cornuta* Boie). One of the most common birds. Very numerous along the roads, its favorite haunts. Apparently raises but one brood, and that very early in the season. (See next list.)

ICTERIDÆ.

38. *Dolichonyx oryzivora* Sw. Not noticed as common.

39. *Molothrus pecoris* Sw. Much less common than in the Eastern States; in consequence, doubtless, of the comparative scarcity of the smaller birds, its foster parents, as noted in the preceding list.

40. *Agelæus phœniceus* Vieill. Common.

41. *Sturnella magna* Sw. Very abundant, and as tame as Sparrows. Roads are among their favorite haunts, where, in company with *Eremophila cornuta,* they will often permit vehicles, and even persons on foot, to pass within ten or a dozen yards of them.

42. *Icterus Baltimore* Daud. Rather common, yet far from abundant.

43. *Icterus spurius* Bon. Rather less common than the preceding.

44. *Quiscalus versicolor* Vieill. Common.

CORVIDÆ.

45. *Cyanura cristata* Sw. Very abundant and half domestic. The presence of this species in cultivated grounds, and its general familiarity, seem due as much to the scarcity of its inveterate persecutors, the Robins, Kingbirds, and other smaller birds, who are so painfully aware of its piratical practices, as to the kind treatment it receives from the farmers, who not only do not molest it but are pleased with its presence. Young fully fledged, June 20.

46. *Corvus americanus* Aud. Apparently not very common in summer. At the West this bird has a better character than at the East; never, it is said, does it pull corn, and it is much less suspicious, — being perhaps conscious of its innocence, and presuming upon the good treatment from the farmer which it not only merits but receives.

TYRANNIDÆ.

47. *Tyrannus carolinensis* Baird. Not very common.

48. *Sayornis fuscus* Bd. Common.

49. *Contopus virens* Cab. Comparatively common.

50. *Empidonax minimus* Bd. Not common.

Alcedinidæ.

51. *Ceryle alcyon* Boie. Common.

Caprimulgidæ.

52. *Antrostomus vociferus* Bon. Remarkably abundant. I never saw them elsewhere so numerous.

53. *Chordeiles popetue* Bd. Very common.

Cypselidæ.

54. *Chætura pelasgia* Steph. Not very common.

Trochilidæ.

55. *Trochilus colubris* Linn. Common.

Cuculidæ.

56. *Coccygus erythrophthalmus* Bon. Common.

57. *Coccygus americanus* Bon. Rather common.

Picidæ.

58. *Picus villosus* Linn. Not very common.

59. *Picus pubescens* Linn. Common.

60. *Sphyrapicus varius* Bd. Not common.

61. *Melanerpes erythrocephalus* Sw. Not common.

Though *Centurus carolinus* probably occurs, it was not seen. From the scarcity of forest this family was not numerously represented.

Falconidæ.

62. *Accipiter fuscus* Bon. Not uncommon.

63. *Buteo borealis* Vieill. Frequent about the belts of timber, particularly in the autumn.

64. *Circus hudsonius* Vieill. Abundant. The most common hawk; the prairies are its favorite hunting grounds.

Strigidæ.

65. *Bubo virginianus* Bon. Not common.

66. *Scops asio* Bon. Rather common.

67. *Syrnium nebulosum* Gray. Rather common.

Probably *Brachyotus* "*Cassini*" is also not rare, though I failed to detect it.

Columbidæ.

68. *Ectopistes migratorius* Sw. Generally numerous in fall and spring, when it is often excessively abundant, but is not common in summer, and but rarely breeds.

69. *Zenædura carolinensis* Bon. Exceedingly abundant, and half domestic.

Tetraonidæ.

70. *Cupidonia cupido* Bd. More or less abundant on the prairies.

71. *Bonasa umbellus* Steph. Very numerous in the groves.

Perdicidæ.

72. *Ortyx virginiana* Steph. Very abundant.

CHARADRIIDÆ.

73. *Ægialitis vociferus* Cass. Very common.

SCOLOPACIDÆ.

74. *Tringoides macularius* Gray. Common.

75. *Actiturus Bartramius* Bon. Very common, and quite unsuspicious.

76. *Philohela minor* Gray. Abundant.

77. *Phalaropus Wilsoni* Sab. As this species is known to breed in the Fox River and Calumet marshes, it may well be included in the present list, though I did not actually observe it.

ARDEIDÆ.

78. *Ardea herodias* Linn. Rather common.

79. *Botaurus lentiginosus* Steph. Common.

80. *Butorides virescens* Bon. Common.

81. *Nyctiardea Gardeni* Baird. Common.

RALLIDÆ.

82. *Rallus virginianus* Linn. Not uncommon.

ANATIDÆ.

83. *Aix sponsa* Boie. Common.

Probably a few *Anas boschas* and *A. obscura* breed in the more secluded marshes; while in spring and fall numerous species of ducks and geese occur in very great abundance.

LARIDÆ.

84. *Hydrochelidon fissipes* Gray. Common along the Fox River marshes.

B.— Cook County.

TURDIDÆ.

1. *Turdus migratorius* Linn. Common.

2. *Turdus mustelinus* Gmel. Very abundant, and rather easily procured. Not more shy than the next.

3. *Turdus Swainsoni* Cab. (*T. Swainsoni* and *T. Aliciæ* Baird, Coues and others.) Very abundant, and presenting its usual range of variation in color.

Four additional seasons of investigation, with opportunities for a very careful examination of large series of both *T.* "*Swainsoni*" and *T.* "*Aliciæ*," sent to different museums by the Smithsonian Institution, and chiefly labelled in Prof. Baird's handwriting, numbering altogether more than twenty specimens, have fully confirmed the conclusions arrived at by me from an examination of a great number of fresh specimens obtained in Massachusetts, and published four years since in the Proceedings of the Essex Institute (Vol. IV, Aug. 1864, p. 56). These were, that the stage of plumage characterized as *T. Aliciæ* did not form "even a well-marked variety," but that the two conditions of plumage, supposed indicative of two species passed into each other by almost imperceptible gradations; and that the variations in size and proportions, both of which Prof. Baird supposed to furnish valid distinctions, are as inconstant as color, and do not by any means accord with the variations in color, the larger size accompanying the ashy-olivaceous tints, and the smaller the rufous-olivaceous, as his diagnoses in "Birds of North America" (P. R. R. Rep. IX, 217) would have them. At the Museum of the Chicago Academy of Sciences, I had, last season, an opportunity to examine some twelve or fifteen authentic specimens of *T.* "*Aliciæ*," including specimens from about Chicago, the locality whence "*Aliciæ*" was first described, and which, I was told, were labelled by the late R. Kennicott, as well as others from various parts of North America, including some from La Pierre House, Fort Anderson, and other extremely northern localities, which had been received by the Academy from the Smithsonian Institution, and were labelled in the handwriting of Prof. Baird. These, as already stated, bear out our conclusions published in the Proceedings of the Essex Institute as cited above. The intermediate stages are evidently very perplexing to those who consider *T.* "*Swainsoni*" and *T.* "*Aliciæ*" as two distinct species, more than half the labels of the Smithsonian specimens in the Chicago Academy and in the Museum of Comparative Zoölogy, being written "*T. Swainsonii?*", or "*T. Aliciæ?*", while in addition to the query, the word "hybrid" or "hybrid?" is often added.

We may also add that instead of *T.* "*Aliciæ*" being restricted in its range to the Mississippi Valley, as was at first supposed, it comes from every part of North America inhabited by *T. Swainsoni*, which at different seasons is nearly the whole continent; thus Dr. Coues gives it from the District of Columbia and Labrador, and others from other points in the Atlantic States, while I have found it as common in Western New York as in Massachusetts; it is common in the collections made about Great Slave Lake, along the Mackenzie River, and at Fort Youkon on the Youkon River.

Prof. Baird mentions, in his "Review of American Birds" (p. 21), as "a very remarkable circumstance, that for two or three years past it has been more abundant around Washington than *Swainsonii* itself." In the same connection he alludes to Dr. Coues finding it "abundant in Labrador," but at the same time supposes that during these same years I have mistaken something else for it in Massachusetts, and so have not seen, he says, "what *I call* T. Aliciæ."!

[Since the above was written, Mr. E. A. Samuels has published, in the "American Naturalist" for June of the present year (Vol. II, p. 218),[1] a notice of the occurrence of the "Dwarf Thrush (*Turdus nanus*) in Massachusetts." Some months since, I had the pleasure of examining the specimen alluded to, and unhesitatingly referred it to *Turdus Swainsoni;* it differs from the average of specimens only in its somewhat smaller size, and in certain very distinct marks of immaturity. Through the kindness of Mr. L. L. Thaxter, the owner of the specimen, I have since had the opportunity of reëxamining it, the second examination confirming this opinion. I am hence not surprised that Mr. Samuels (see his account) found it so distinct from *Turdus Pallasi*, with which alone he seems to have compared it; but his description, though in the main accurate, contains, in the statement that the color becomes "paler *on the rump to the upper tail coverts*, which are rufous," a tangible and rather important error, inasmuch as there is no very appreciable difference of color in the different portions of the dorsal plumage, which is of the general uniform character peculiar to *T. Swainsoni*, with no approach to the contrast between different regions seen in *T. Pallasi*,

[1] I learn that the same account also occurs in the second edition of Mr. Samuels "Ornithology and Oölogy of New England."

which his description leads one to expect. The specimen is of the ferruginous type of *T. Swainsoni*, having this tint rather unusually intense throughout, both above and below. It has, moreover, each feather of the outer row of coverts, and two or three of the inner secondaries tipped with a conspicuous drop-shaped spot of pale rufous, the tips of the coverts thus forming a light band across the wing, a condition often seen in this genus, in birds of the year. (The specimen was collected October 9, 1867.)

Another specimen of this species (*T. Swainsoni*), worthy of notice in this connection, was collected in Newton (Mass.), by Mr. C. J. Maynard, May 25, of the present year. In size it nearly corresponds with the one referred to above, being fully as small, and like it bearing traces of immaturity, in the small drop-shaped spots of pale rufous tipping the greater wing-coverts. The base of the lower mandible is also more decidedly yellow than in average specimens, a color which is exceedingly variable in all our Thrushes, though perhaps most notably so in the Robin (*T. migratorius*). In color, especially the color of the bill, it accords with Audubon's figures of *T. nanus* in his Birds of America (fig. 147); but does not at all agree, except in size, with his description of the same. In general color it is very much paler than Mr. Thaxter's specimen. Another specimen before me, collected near the same time and place by Mr. Maynard, is so much larger, that if the birds came from localities a thousand miles apart, few ornithologists would fail to consider them specifically distinct; but in reality a connecting series from nearly the same locality fully substantiates their identity. We append the measurements of the three specimens in question, remarking that there is also quite as much difference in color as in size; but the two nearest alike in measurements differ most in color! The first was taken in October, and the others in May, and all within five miles of the same point.

Coll. No.		Sex.	Length.	Expanse.	Wing.	Tail.	Bill.	Tarsus.
—	*Turdus Swainsoni* . .	♂	6.70	10.56	3.50	2.80	0.54	1.05
608	" "	♀	7.00	10.65	3.35	2.45	——	1.15
646	" " . . .	♂	7.76	12.65	4.20	3.10	0.57	1.15

As has been observed, both the smaller specimens are undoubtedly young birds, of probably less than a full year. The length and alar expanse were taken from the specimens when fresh, by the collector; the others from the skin; the length of the culmen is the measurement given for the bill.]

4. *Turdus Pallasi* Cab. Abundant a little earlier in the season.

Among the specimens of this species in the museum of the Chicago Academy from this county, is one a little darker colored than usual, labelled, I think by Mr. R. Kennicott, "*Turdus silens*." During my investigation, four and five years since, of the *Swainsoni* and *Aliciæ* question, I noticed such great and analogical differences in Massachusetts specimens of *T. fuscescens* and *T. Pallasi* as led me to believe that *T. ustulatus* and *T. nanus* were to these species respectively what *T.* "*Aliciæ*" is to *T. Swainsoni*; simply individual variations and not distinct species. Further opportunities for investigation in the mean time, with authentic specimens of *T. nanus* and *T. ustulatus* for comparison, have but fully confirmed these convictions; and I now as confidently add *Merula silens* Swain. (Fauna Boreali-Americana, II, 186, = *T. Auduboni* Baird, Review Am. Birds, 16), to the synonyms of *T. Pallasi.* My reason for this is that a large series of specimens of *T. Pallasi* and *T. fuscescens* from the Eastern States will usually afford those that in every respect match specimens of *T.* "*nanus*" and *T.* "*ustulatus,*" labelled as such at the Smithsonian Institution, with every possible grade between these and the more common type. The variations in size and in the proportion of parts that have been pointed out, it is easy to show are but irregular individual variations, which, as already noted in the case of *T. Swainsoni*, do not accord with the variations in color; moreover, they are only such variations, differing neither in character nor amount, as specimens of almost any undoubted species, taken from a single locality, will present.[1] Hence the only constant distinction is that of the degree of intensity of the rufous tint, which, we should particularly note, varies alike throughout the plumage, being more or less intense above as it is more or less intense below; since the number and size of the spots which have been alluded to as distinctive features are evidently of very little value, if of any,— these, in birds having this style of coloration, being the most inconstant of characters, as a reference to the *Dendrœcæ* and to the various genera of streaked sparrows so well shows. In accordance with the degree of intensity of the rufous, we find the species in question naturally falling into two groups: the first composed of *T. Pallasi* Cab., *T. fuscescens* Steph. and *T. Swainsoni* Cab., characterized by a very marked degree of rufous suffusion throughout the plumage; and the second, of *T. nanus* Aud., *T. Auduboni* Bd., *T. ustulatus* Nutt. and *T. Aliciæ* Bd., and characterized by their general almost entire absence of buff or rufous tints below, leaving this aspect lighter or more ashy, and the purer olivaceous color of the dorsal aspect, due to a like diminution of the ferruginous. In regard to an explanation of this difference in color, it seems to some extent to be merely an irregular individual variation, but a careful general examination of the subject shows that young birds are prone to a suffusion, sometimes of rufous, sometimes of plumbeous, olivaceous, or yellow, the color varying in different species, from which when fully mature they are generally nearly or quite free. As is well known, it is a pretty constant feature of young birds in their first autumn, and even often serves to distinguish specimens of the second and third years among the song-birds, and still later among some of the marine and rapacious, from those of greater age. In the *Oscines* generally, we have good reason to believe that after a certain period birds marked by unusually bright tints, as in *Pinicola*, *Curvirostra*, *Carpodacus*, *Pyranga*, *etc.*, the intensity of the color declines with the increase of age, its maximum seeming to be when the birds first fully reached maturity. This is further borne out by actual observation in cage birds; and it accords with the general law in the animal kingdom of the waning of color with the decline of life. We are hence led to believe that the comparatively small proportion of birds coming under the second group are mainly very old birds, while specimens coming under the first, embracing the great majority, represent the normal or usual condition of plumage. This view is further borne out by the fact that young birds of *T. fuscescens*, raised in Massachusetts, as I have repeatedly observed, as well as autumnal specimens of *T. Swainsoni* and *T. Pallasi*, known from other characters to be such, present this rufous suffusion at its maximum of

[1] An authentic specimen of *T. nanus* (No. 45,904, Smith. Inst. Cat.) collected at Sitka in May 1866, by F. Bischoff, has the wing measuring 3.55, the tail 3.00, the culmen .30, and the tarsus 1.10; while an authentic specimen of *T. Pallasi* (No. 31,414, Smith Inst. Cat.) from Racine, Wis., has the wing 3.45, the tail 2.80, culmen .35, and tarsus 1.10; the specimens differ only in the rather larger bill of the latter, and its more rufous plumage, while the general size of the *T. Pallasi* specimen is *less* than that of the *T. nanus*, showing the inconstancy of the "smaller size" supposed distinctive of *T. nanus*.

intensity; favoring the idea also that the extreme examples in either case are the results of extremes in age, the mean or ordinary really, of course, being alone typical. But there are exceptional examples of birds unmistakably very young and very pale in color, that have the rufous suffusions at a minimum; which tends to show that the variation is by no means to be wholly accounted for on the theory of differences in age.

The difference in distribution once considered to exist between the species of the first and second groups, the second having been considered the western representatives of the first, especially in the case of *T. nanus* Aud., and *T. ustulatus* Nutt., described originally from the Columbia River,[1] does not appear to really exist, since specimens which are exact counterparts of the western occur in the Atlantic States.

Another point not unlikely to be urged as a valid distinction, is the supposed difference in the breeding habits, and in the color of the eggs of *T.* "*nanus*" and *T.* "*ustulatus*" on the one hand, and of *T. Pallasi* and *T. fuscescens* on the other, the two latter laying unspotted deep-green eggs, and nesting on the ground, while the two former nest in trees a few feet from the ground, and lay pale-green eggs, speckled more or less thickly with pale rufous. But in this connection two things are to be noticed: first, the remarkably close resemblance of both the nests and the eggs of *T.* "*nanus*" and *T.* "*ustulatus*," as well as of *T.* "*Aliciæ*," to those of *T. Swainsoni*; second, that these nests all come from places where *T. Swainsoni* is known to breed.

In two nests, labelled respectively "*T. Swainsoni*" and "*T. ustulatus*," presented by the Smithsonian Institution to the Museum of Comparative Zoölogy, the resemblances are as close in the materials, which are quite peculiar, of which the nests are composed, and in the color and markings of the eggs, as we often find in two nests and their eggs of different individuals of the same species. In all of the several sets of eggs of *T.* "*nanus*" and *T.* "*ustulatus*" I have seen, there is the same close resemblance in all cases to those of *T. Swainsoni*, while on the other hand they differ widely from those of their much nearer allies, *T. Pallasi* and *T. fuscescens*. So there appear to be strong grounds for suspecting they are all really nests and eggs of *T. Swainsoni*; the strong general resemblances between the dark olivaceous stages of plumage of the three species (*T. Pallasi*, *T. fuscescens*, and *T. Swainsoni*) being very likely to mislead collectors.

As pertinent to the subject, we add a few observations on the value of certain characters generally considered among birds as specific, as, particularly, the proportions of the primary quills, and the size of different parts. The relative lengths of the primary quills, so commonly dwelt upon even now as affording distinctive specific characters, are really variable and hence, artificial characters. Besides their having a greater or less range of variation in mature birds of the same sex, they also vary with age. The general form of the wing seems to be a generic rather than a specific character, and is, besides, from an embryological point of view, often an important guide to the relative rank of genera in their respective families. In examining very young nestlings, we find that the quills in most birds, and always in the true *Oscines*, all appear in sight at once, and that at first they are so nearly alike that it is impossible to say which is the longer or thicker, or what, judging from this stage alone, is to be the ultimate form of the fore-wing. Very soon, however, a change begins, and those primaries eventually to be the longest, whether the first and

[1] The first specimen of *T.* "*nanus*" Audubon ever saw, however, we are led from his remarks to believe, was derived from Pennsylvania. See *Orn. Biog.* vol. v, p. 201.

second, or the fifth, soon outstrip the others in growth, the wing in its increase approaching more and more, through the different degrees of rapidity of growth of the different quills, to its final form, — normally the quills all ending their growth, as they commenced it, simultaneously. But with the first set the mature form for the species is not always reached, nor, in some groups, with the second; young birds, in genera with the middle primaries longest in the mature wing, having the wing more rounded than the fully adult. This I have seen exemplified in different species, but it is a fact especially marked in *Chrysomitris tristis;* in which, besides the difference in this respect between young and fully mature birds, there is a similar one sometimes exhibited in the different sexes, the female often having a more rounded and hence less perfect wing than the male. This latter I have noticed also in other species, it being apparently more common in those with marked sexual differences in plumage. Yet how often do we find definite wing formulas given in specific diagnoses as though they were characters of the utmost value, proportional differences in the primaries being cited as conclusive evidence in eking out other faint indications of specific diversity! Whereas, the individual range of variation in this respect is often sufficiently great in either of several closely allied species, to cover the general range of all; hence, as already observed, this character of the proportions of the primaries, or of the form of the wing, seems to be a generic rather than a specific one.

In the category of generally approved specific distinctions, that of absolute size, as probably many ornithologists are now aware, is too variable to be a really distinctive feature in strictly congeneric species. Thus the range in variation in measurement afforded by either *T. Pallasi* or *T. Swainsoni*, or of *T. fuscescens*, will cover the common range of the three, a case of by no means rare occurrence. But the relative size of different parts has been looked upon almost universally, and most naturally, as among the ultimata in specific distinctions. But here, in making a large series of detail measurements, amounting to twenty or more for each bird, I have been astonished at most unlooked-for variations in individuals of the same species and sex, *from one and the same locality*, the variations amounting in some cases, as, for example, in *Colymbus torquatus*,[1] to twenty-five per cent. of the general mean; while in many small birds, as in different species of *Fringillidæ*, *Sylvicolidæ*, and *Turdidæ*, it is almost as much, though less marked to the casual observer, from the smaller size of the birds. Through these variations we find in the same species both slender and stout-built birds, in which the character of slenderness or stoutness extends to all the different parts; also long tarsi accompanying short toes, long wings a short tail, or a short tail a long neck, and that bills vary greatly in the proportion of thickness to length, and hence in their general form;[2] differences wholly similar to the variations in stature, build, and general physiognomy observable in any given race or nationality of men. What is claimed from this is, that the fact of a marked individual variation existing among birds has not been hitherto sufficiently recognized, from the fact that a sufficient number of individuals of any species, taken at the *same season* and at *one locality*, have not been critically studied. Hence it is that such differences as some of the above having been for the first time detected in

[1] In a series of fifteen specimens of *C. torquatus* in the Museum of Comparative Zoölogy, all from New England and nearly all from Massachusetts, the variation in the length of the wing in the two extreme specimens amounts to 20 per cent. of the mean of the series; of the tarsus, 29 per cent.; of the outer toe, 30 per cent.; of the head, 28 per cent.; of the culmen, 23 per cent.

[2] As we purpose soon to make public some of the measurements on which these statements are based, we omit further details here.

specimens from distant localities have led to the formation of new species on unwarrantable grounds. From this it is evident that an ornithologist should thoroughly acquaint himself with the amount of the variation in the proportion of parts, as well as in color, and with the laws governing the successive changes in color presented by the plumage during the whole life of the bird, as also the seasonal changes which the birds about him present, before he is fully qualified to deal with those from distant regions, of which he can see but a limited number of prepared specimens. Besides the variations presented by the representatives of any species at the same locality, there are others that may be termed geographical, depending as they do upon variation in the nature of the habitat, the exact character and extent of which we as yet know little; but that nearly every species occupies in the breeding season a wide range in latitude, and in many cases markedly so, has already been too fully demonstrated — thanks especially to the thorough elaboration by Prof. Baird and his collaborators, of the immense collections of North American birds brought together at the Smithsonian Institution — to admit of reasonable doubt.[1] As to what other characters also vary with the locality, we have less positive assurance; though the paler color of specimens coming from the Middle or Rocky Mountain Plateau region of the continent, in species ranging from the Atlantic to the Pacific, compared with specimens from the Atlantic or Pacific slopes, is now known in too many species[2] to be considered as an accidental circumstance. These facts of variation should not, it is evident, lose their weight in considerations of specific diversity in obscure cases, and especially when the specimens are from new or little known localities. Yet the geographical difference in size is even now occasionally, but of course blamably, overlooked by not a few naturalists in their eagerness to add a few more "new species" to their lists.

Species when properly limited, or species in nature, we believe to be tangible things; but many of the zoölogists of to-day are making them the most inconstant and intangible of all objects — a mere matter of opinion and locality, in fact, — of which the Thrushes under consideration, and especially the American *Turdidæ* generally, furnish a good, but, unfortunately, not a solitary illustration in American birds. If we admit seven species in the group in question as inhabitants of the United States, I see no reason why, on similar grounds, we may not further increase the number. But if we restrict them to three — *Turdus Pallasi*, *T. Swainsoni*, *T. fuscescens*, — we have three that are well marked and well separated, with rarely, if ever, a specimen occurring that may not with the greatest confidence be referred to one or the other.

We have already seen (*antea*, pp. 508–9), that individuals of *Turdus Swainsoni* occur corresponding in size with the typical or original specimens of the so-called species "*Turdus nanus*" and *Turdus ustulatus*, affording parallel grounds for an additional species, which shall hold the same relation to *T. Swainsoni* that these do respectively to *T. Pallasi* and *T. fuscescens*. Once overstepping, then, the restrictions given here, we may go still further, and taking the extremes of size and of color, and the means, have not seven only, nor merely nine, but *eighteen* species! since the extremes and the means in size have each their dark and light colored representatives, depending upon the intensity of the rufous tint. Palpably

1 For the first formal statement of this law of variation in size with latitude, see Prof. Baird on the "Distribution and Migration of North American Birds." *Am. Journ. of Sc. and Arts*, [2] vol. xli., March 1866.

2 Among these species we may enumerate *Poœcetes gramineus*, *Sturnella magna*, *Chordeiles popetue*, *Eremophila alpestris*, *Bubo virginianus*, *Buteo borealis*; and probably add *Turdus Pallasi* ("*Auduboni*"), and perhaps the other *Turdi*.

absurd as this may seem, the principle, or lack of principle, or of consistency, necessary for the admission of *T. Aliciæ, T. nanus, T. Auduboni* and *T. ustulatus* will even warrant this extreme.[1]

[1] We append here the more important synonyms of the three species of *Turdus* under consideration, with short diagnoses of each.

TURDUS PALLASI.

Turdus solitarius WILSON, Am. Orn., V, 1812, 95; not the fig. (Pl. xliii, 2), which is of *T. Swainsoni.* Not the *T. solitarius* of Linn.
" " BONAPARTE, Geog. and Comp. List., 1838.
" " AUDUBON, Syn., 1839 ; *ib.* Birds of Am., III, 1841, 29, Pl. 146.
Merula solitaria SWAINSON, Faun. Bor. Am., II, 1831, 184, Pl. 37.
" " BREWER, Proc. Bost. Soc. Nat. Hist., I, 1844, 191.
" *silens* SWAINSON, Faun. Bor. Am., II, 1831, 186.
Turdus minor BON., Obs. on Wilson's Nomenclat., 1825, No. 72.
" " NUTTALL, Man. Am. Orn., I, 1830, 346.
" " AUD., Orn. Biog., I, 1831, 303; *ib.* v, 445, Pl. 58.
" " GIRAUD, Birds Long Island, 1843–44, 90.
" *Pallasi* CABANIS, Weigm. Archiv, 1847, I, 205.
" " BAIRD, Birds N. Am., 1858, 212; *ib.* Rev. Am. Birds, Pt. I, 1864, 14.
" " SAMUELS, Orn. and Oöl. N. Eng., 1867, 148.
" *nanus* AUD., Orn. Biog., V, 1839, 201; *ib.* Bds. Am., III, 1841, 32.
" " GAMBEL, Proc. Phil. Acad. Nat. Sc., I, 1843, 262.
" " BAIRD, Birds N. Am., 1858, 213; *ib.* Rev. Am. Bds., Pt. I, 15.
" *Auduboni* BAIRD, Rev. Am. Bds., Pt. I, 16.

SP. CH. — Above pale olive brown, occasionally inclining to rufous, passing into bright rufous on the tail coverts and tail, becoming most intense on the latter. Below, pale brownish olive, passing into white on the middle of the abdomen and throat, and into darker on the sides, with well-defined triangular spots of very dark olivaceous brown, or sometimes nearly black, on the sides of the neck and breast, extending as far back as the middle of the abdomen. A more or less appreciable band of pale buff across the upper breast, with sometimes a tinge of the same on the throat. Specimens collected at the same locality and season are variable in respect to the intensity of the color above, and in respect to the size and depth of the color of the spots below, and the distinctness of the buff breast band. Young generally, even of the second year, with a pale band across the wings, formed by the lighter tips of the outer row of greater coverts. Readily distinguishable from its allies by the contrast in color between the tail and the back.

TURDUS SWAINSONI.

Turdus minor GMELIN, Syst. Nat., I, 1788, 817; in part only.
" " VIEILLOT, Ois. Am. Sept., II, 1807, 7, Pl. 63 ; in part only.
Turdus minor BONAPARTE, Geog. and Comp. List., 1838; *ib.* Consp., 1850, 271.
" *solitarius* WILSON, Am. Orn., V, Pl. 13, fig. 2 ; figure only.
Merula " SWAINSON, Faun. Bor. Am., II, 1831; Pl. 36; figure only.
" *Wilsoni* SWAINSON, " " " 1831.
Turdus olivaceus GIRAUD, Birds Long Island, 1843–44, 92 Not *T. olivaceus* of Linn.
Merula " BREWER, Proc. Bost. Soc. Nat. Hist., I, 1844, 191.
"*Turdus Swainsoni* CABANIS, in Tschudi Fauna Peruana, 1844–46, 188."
" " BAIRD, Birds N. Am., 1858, 216; *ib.* Rev. Am. Bds., Pt. I, 19.
" " ALLEN, Proc. Essex Inst., IV, 1864, 56.
" " SAMUELS, Orn. and Oöl. of N. Eng., 1867, 152.
" *Aliciæ* BAIRD, Birds N. Am., 1858, 217; *ib.* Rev. Am. Bds., Pt. I, 21.
" " COUES and PRENTISS, Smiths. Rep., 1861, 405.
" " COUES, Proc. Phil. Acad. Nat. Sc., 1861, 217.
" *nanus* SAMUELS, Am. Nat., II, June, 1868, 218.

SP. CH. — Above nearly uniform dark olive, with a more or less decided tinge of green. Below much like *Turdus Pallasi*, in some cases, in fact resembling it quite closely, but generally with the triangular spots smaller and less sharply defined, and with a more decided suffusion of buff on the breast and neck. Extent of the spotting posteriorly variable, sometimes covering only the upper breast, sometimes reaching the middle of the abdomen. Exceedingly variable in the degree of rufous pervading the plumage, which is sometimes strongly marked and again is scarcely appreciable; in the former case giving a strong buff tinge to the sides of the head, neck, and breast; in the latter leaving these ashy, and the general plumage above of a darker or greener olive. In this latter stage it forms the *T. Aliciæ* of authors.

TURDUS FUSCESCENS.

Turdus mustelinus WILSON, Am. Orn., V, 1812, 98, Pl. 43. Not *T. mustelinus* of Gmelin.
" *fuscescens* STEPHENS, Shaw's Zoöl., X, i, 1817, 182.
" " GRAY, Genera of Birds, 1849.
" " BAIRD, Birds N. Am., 1858, 214 ; *ib.* Rev. Am. Bds., Pt. I, 17.
" " SAMUELS, Orn. and Oöl. of N. Eng., 1867, 150.
" *Wilsoni* NUTTALL, Man. Am. Orn., V, 1832, 349.
" " AUDUBON, Orn. Biog., II, 1834, 362; *ib.* V, 446; Pl. 166.
" " GIRAUD, Bds. of L. Ild., 1843–44, 89.
Turdus Wilsoni BREWER, Proc. Bost. Soc. Nat. Hist., I, 1844, 191.

The genus *Passerculus* affords another eminent example of the doubtful nature of species, if we allow the five described in the General Report on North American Birds to be distinct. On the other hand, if we refer all to *P. savanna*, we have one positive species, with at the same time a range and a character of variation not at all unusual; the differences in size between some of the supposed species being just such as we should expect in the different localities from which the specimens come in any species with the same range of latitude. So in *Cyanura*, of which we have one species, the *C. cristata* Swain., in the eastern half of the United States, presenting considerable variations in depth of color, and in the size and shape of the bill and crest, and in the western half its congeneric representative, *C. Stelleri* Swain., with strictly analogous variations, but on which ornithologists have based several so-called species, (as *C. coronata* Swain., *C. macrolophus* Bd., etc.), all so closely allied that we find their authors expressing grave doubts of their validity. The genus *Ægiothus* gives us another example of *seven* closely allied species, according to a recent authority,[1] while still others have been indicated by Brehm, where even *two* cannot be positively defined, and all should probably be referred to one; the variations in size agreeing with the common variations in other species according to latitude, and those of color, shape of the bill, etc., with numerous parallel cases in undoubted species of *Sylvicolidæ*. It is a source of surprise to me that ornithologists contend persistently for the existence of species where the characters on which they are based are so slight that in repeated instances they admit the distinction to

Merula minor SWAINSON, Faun. Bor. Am., II, 1831, 179, Pl. 36.
Turdus ustulatus NUTTALL, Man. Am. Orn., I, (2d ed.), 1840, 400.
" " BAIRD, Birds N. Am., 215; *ib.* Rev. Am. Bds., Pt. I, 1864, 18.

SP. CH. — Above nearly uniform reddish brown. Below white; sides pale ashy brown; neck in front and breast pale yellowish brown, but very variable in intensity in specimens collected at the same locality and season, as is also the color above; breast and fore neck with small triangular or sublinear spots, generally like the back, but sometimes decidedly darker. Sometimes they are very conspicuous, equalling in size occasional extreme specimens of *T. Swainsoni*, and again are nearly obsolete. Specimens with these larger and well defined spots accord with what authors call *T. ustulatus*. Differs from *T. Swainsoni* through a general difference in color, especially of the upper parts, and in the character of the markings below. Also from *T. Pallasi* in this last respect, and also in the uniformity in the color of the upper parts.

The three species above characterized have in coloration no single general character in common. Two (*T. Pallasi* and *T. Swainsoni*) agree occasionally quite nearly in that of the ventral aspect, but a glance at the dorsal suffices to separate them. Two (*T. Swainsoni* and *T. fuscescens*), also agree in the uniformity of the color above, but it generally differs widely in tint, while a glance at the ventral surface suffices at once to distinguish them. Each has a considerable range of color variation, regardless of sex, season, or locality; it is, however, to a greater or less degree, unmistakably connected with age.

[1] DR. ELLIOT COUES, *Monograph of the Genus Ægiothus*, Proc. Acad. Nat. Sc., Philadelphia, Nov. 1861. In justice to Dr. Coues I should add, that, after the examination of more material received at the Smithsonian Institution, in some *Additional Remarks on the North American Ægiothi*, (same Proc., Feb. 1863), his doubts of the validity of two species, *Æ. rufescens* and *Æ. Holbölli*, had become considerably strengthened. In this connection he mentions a highly suggestive series of skins collected in winter in the vicinity of Quebec. "Selecting from the series two or three skins which differ most markedly from the usual style of *linarius*, and comparing with typical specimens from Philadelphia," he found a marked difference in size, while, save slight differences in the color of the bill and throat, the birds were otherwise "quite identical." "But now, on examining in detail, the rest of the series," he continues, "I find that, from the one extreme, the characters of which have just been given, there is a complete and gradual transition — a diminution in size, down to specimens which cannot possibly be distinguished from typical *linarius*. There is no break in the series, no dividing point where we can stop calling the specimens 'linarius' to give them another name, in spite of the discrepancy so evident between the two extremes."

Several winters since *Ægiothus linarius* was excessively abundant at Springfield (Mass.) for two months, during which time I killed and examined great numbers of specimens, and in which I noticed considerable variations in size, as well as in the depth of color of the general plumage, specimens varying from light to dark tints, with varying amounts of rufous, besides the common variations in the rosaceous and carmine tints, without being able to satisfy myself that the immense flocks sweeping about over the fields or unsuspiciously feeding, embraced more than one species, though I was searching among them for a second. They remained till April, and before they left, the rosaceous tints in the males had markedly increased.

rest mainly on *locality*, as though beyond a certain geographical range species *must* be different whether or not the difference is evident! Furthermore, that while they are so acute to detect differences, and place so much weight upon those of a trivial character, that they should be so unmindful of resemblances, and so unheedful of their suggestions. But having already many times exceeded the limits proposed for this digression, we resume the list of the birds of Cook County.

5. *Harporhynchus rufus* Cab. Common. May 27 found a nest with one egg. Nest in a large oak, supported by small twigs on the side of the trunk, about eight feet from the ground,—the first case I have known of this bird building so high from the ground. The birds were very bold in the defense of their nest, approaching within two feet of it when my hand was upon it.

6. *Galeoscoptes carolinensis* Cab. Common.

SAXICOLIDÆ.

7. *Sialia sialis* Bd. Common.

PARIDÆ.

8. *Parus atricapillus* Linn. Common.

TROGLODYTIDÆ.

9. *Troglodytes ædon* Vieill. Common.

10. *Troglodytes hyemalis* Vieill. Common.

11. *Cistothorus stellaris* Cab. Not uncommon about marshes.

12. *Cistothorus palustris* Cab. Common in the marshes. Both this and the preceding said to breed numerously, especially in the Calumet marshes.

SYLVICOLIDÆ.

13. *Dendrœca Blackburniæ* Bd. Abundant.

14. *Dendrœca virens* Bd. Abundant.

15. *Dendrœca æstiva* Bd. Abundant.

16. *Dendrœca cœrulescens* Bd. (Rev. Am. Bds.; *D. canadensis* Bd., Birds of N. Am.) Very common.

17. *Dendrœca pennsylvanica* Bd. Abundant.

18. *Dendrœca striata* Bd. Abundant.

19. *Dendrœca castanea* Bd. Very common, but less numerous than either of the preceding.

20. *Dendrœca coronata* Gray. Abundant.

21. *Perrisoglossa tigrina* Bd. (Rev. Am. Bds.; *Dendrœca tigrina* Bd., Birds of N. A.) Rather common, but much less so than most of the preceding species of this family.

22. *Wilsonia pusilla* Bon. Rather common.

23. *Wilsonia mitrata* Bon. Took two or three in a couple of days' collecting.

24. *Helminthophaga peregrina* Bd. Collected several. Apparently not rare.

25. *Helminthophaga ruficapilla* Bd. But few seen. Apparently not much more numerous than its congener preceding.

HIRUNDINIDÆ.

26. *Hirundo horreorum* Barton. Abundant.

27. *Petrochelidon lunifrons* Bd. (*Hirundo lunifrons* Say.) Abundant.

28. *Cotyle riparia* Boie. Very abundant. Nesting in great numbers in the low bluffs along the lake.

29. *Progne subis* Bd. (*P. purpurea* Vieill.) Common.

VIREONIDÆ.

30. *Vireosylvia olivacea* Bon. Abundant.

31. *Vireosylvia Philadelphica* Cass. Collected several; is apparently quite common.

32. *Lanivireo solitarius* Bd. Common.

LANIIDÆ.

33. *Collurio excubitoroides* Bd. Not very uncommon. Breeds, laying its eggs quite early in May (F. J. Huse).

TANAGRIDÆ.

34. *Pyranga rubra* Vieill. Very common.

35. *Pyranga æstiva* Vieill. Not seen, but on good authority said to occur.

FRINGILLIDÆ.

36. *Chrysomitris tristis* Bon. Common.

37. *Passerculus savanna* Bon. Frequent.

38. *Poœcetes gramineus* Bd. Rather common.

39. *Coturniculus passerinus* Bon. Rather common.

40. *Chondestes grammaca* Bon. Repeatedly observed, and probably not uncommon.

41. *Zonotrichia leucophrys* Swain. Quite common.

42. *Zonotrichia albicollis* Bon. Common.

43. *Spizella pusilla* Bon. Not apparently common.

44. *Spizella socialis* Bon. Not conspicuously numerous, as at the east.

45. *Melospiza melodia* Bd. Rather uncommon. Indeed it was so scarce that we rarely noticed it.

46. *Melospiza Lincolnii* Bd. Common. Much more numerous than the preceding.

47. *Melospiza palustris* Bd. Very common. Probably much the most numerous species of the *Melospizæ* found here.

48. *Euspiza americana* Bon. Common.

49. *Hedymeles ludoviciana* Cab. (*Guiraca ludoviciana* Swain.) Common.

50. *Cyanospiza cyanea* Bd. Common.

51. *Pipilo erythrophthalmus* Vieill. Abundant.

In winter, according to my friend Mr. F. J. Huse of Evanston, the northern species of this family, as *Spizella monticola* Bd., *Ægiothus linarius* Cab., both Crossbills, *Plectrophanes nivalis* and *P. lapponicus*, and *Pinicola enucleator* (*P. canadensis* Cab.) occur, some of them regularly and others irregularly, about as in the Atlantic States, excepting perhaps *P. lapponicus*, which is more common at the west. The prominent difference in the representation of this family here and in New England at this season (May), is in the relative scarcity here of the *Spizellæ* and *Melospiza melodia*, the most numerous species in New England, and the greater commonness of *Melospiza Lincolnii*, *Euspiza americana*, and *Zonotrichia leucophrys*, the first two being almost unknown there, while *Chondestes grammaca* is wholly superadded, giving, as will be seen, quite a different aspect to this section of the avi-fauna. The addition of the next, a near ally of the sparrows, makes the difference apparently still greater.

I may here add that in Wayne County, New York, I found *Z. leucophrys* exceedingly common, far outnumbering *Z. albicollis.* In a single day I often saw more than I have in ten years in Massachusetts.

Alaudidæ.

52. *Eremophila alpestris.* (*E. cornuta* Boie.) Abundant. Shot fully fledged young, May 25, showing that they nest very early. I met with no young birds, nor saw indications that the species was nesting later in the season, though it was present wherever I went throughout the summer; hence I infer that they rear but one brood a year, and that very early, probably laying their eggs by the first of April.

Icteridæ.

53. *Molothrus pecoris* Swain. Common.

54. *Dolichonyx oryzivorus* Swain. Common.

55. *Agelæus phœniceus* Vieill. Abundant.

56. *Xanthocephalus icterocephalus* Bon. Seen flying over. Said to breed in great numbers in the Calumet marshes.

57. *Sturnella magna* Swain. Abundant. Notes appreciably different from those of its representatives in New England, approaching in the variation those of the so-called *S. neglecta.*

58. *Icterus Baltimore* Daud. Not particularly common.

59. *Icterus spurius* Bon. Represented in about the same numbers as the preceding.

60. *Scolecophagus ferrugineus* Swain. Occasional. In October I found this species very abundant in Kalamazoo and Van Buren counties, Mich., occurring in large flocks, and outnumbering all the other Blackbirds; most of the others having perhaps already passed southwards. Among them were specimens referable in every particular to the so-called *S. cyanocephalus.* Beech-nuts seemed its favorite food.

61. *Quiscalus versicolor* Vieill. Common.

Corvidæ.

62. *Corvus americanus* Aud. Common.

63. *Cyanura cristata* Swain. Excessively common, and comparatively domestic, nesting unsuspiciously in the shrubbery and shade-trees of the towns.

Tyrannidæ.

64. *Tyrannus carolinensis* Bd. Common.

65. *Myiarchus crinitus* Cab. Common.

66. *Sayornis fuscus* Bd. Common.

67. *Contopus virens* Cab. Common.

68. *Contopus borealis* Bd. Rather common.

69. *Empidonax minimus* Bd. Common.

70. *Empidonax flaviventris* Bd. Several specimens taken in a couple of days; probably rather common.

Alcedinidæ.

71. *Ceryle alcyon* Boie. Common.

Cuculidæ.

72. *Coccygus americanus* Bon. Frequent.
73. *Coccygus erythrophthalmus* Bon. Frequent.

Picidæ.

74. *Picus pubescens* Linn. Common.
75. *Picus villosus* Linn. Common.
76. *Sphyrapicus varius* Bd. Common.
77. *Melanerpes erythrocephalus* Sw. Very abundant; more numerous than all the other *Picidæ* together.
78. *Centurus carolinus* Bon. Quite common.
79. *Colaptes auratus* Swain. Abundant. It is a well-known fact that when the eggs of this species are successively removed from the nest while the female is laying, that she will continue laying till she has much exceeded her usual number. Mr. F. J. Huse related to me a case within his knowledge, where *twenty* eggs were taken from the same nest, before the female was shot. As might have been expected, she was found to be exceedingly poor in flesh. Had she not at this point been killed, it is impossible to say how many more she would have laid, though undoubtedly several.

From the above list we see that the *Picidæ* are very differently represented here from what they are in the Eastern States, through the almost entire absence there of *Melanerpes erythrocephalus* and *Centurus carolinus*, which here, and especially the former, are predominant species. *Picus pubescens* and *P. villosus* appear on the other hand to be rather less numerous.

In Kalamazoo and Van Buren counties, Mich., the third week in October, I found *C. carolinus* the most numerous woodpecker, *M. erythrocephalus* having in part no doubt gone south. In the dense forests *Hylatomus pileatus* was not rare. At this season *C. carolinus* was very restless and active, running hastily over the trunks and branches of the trees, spending but a minute on one before flying to another, and then to a third, often in a few seconds returning again to the first. Its principal food seemed to be beech-nuts, in gathering which it clung to the twigs like a titmouse, and was rarely seen digging into the decayed parts of the trees for larvæ, as its associates, the Hairy and Downy Woodpeckers, were doing.

Charadriidæ.

80. *Ægialitis vociferus* Cass. Abundant.

Scolopacidæ.

81. *Gallinago Wilsoni* Bon. Common.
82. *Philohela minor* Gray. Common.
83. *Actiturus Bartramius* Bon. Common.
84. *Tringoides macularius* Gray. Common.
85. *Phalaropus Wilsoni* Sab. Common.

ARDEIDÆ.

86. *Ardea herodias* Linn. Not very uncommon.

87. *Botaurus lentiginosus* Steph. Common.

88. *Butorides virescens* Bon. Common.

89. *Ardetta exilis* Gray. Not rare. More common than eastward.

RALLIDÆ.

90. *Rallus virginianus* Linn. Not uncommon in its proper haunts.

91. *Fulica americana* Gmel. This and the preceding are well known to breed in the Calumet and Winnebago marshes, as well as *Phalaropus Wilsoni*.

LARIDÆ.

92. *Larus argentatus*[1] Brünn. (*L. Smithsonianus* Coues, Proc. Phil. Acad. Nat. Sc., 1862, p. 296). Common.

93. *Sterna Wilsoni* Bon. Common.

94. *Hydrochelidon fissipes* Gray. Common.

[1] A careful examination of the question of the specific identity or diversity of the American and European Herring Gulls, with access to the numerous specimens contained in the Museum of Comparative Zoölogy, and to those of the Museums of the Boston Society of Natural History and the Peabody Academy of Science, including among them birds from both countries, for examination and comparison, has not shown apparently the slightest grounds for a separation of the two as distinct species. After the careful examination of the subject by Dr. Coues, (*Revision of the Gulls of North America; based upon specimens in the Museum of the Smithsonian Institution.* By ELLIOTT COUES. Proc. Phil. Acad. of Nat. Sc., June, 1862, p. 291,) with such abundant materials as the Smithsonian Institution affords at his command, I was not a little surprised to find the series of adult American Herring Gulls in the Museum of Comparative Zoölogy presenting characters quite at variance with his diagnosis of this species. Subsequently in a more thorough examination of the subject, aided by a series of above thirty specimens, including, as above stated, representatives from both continents, I became fully convinced of their identity. Specimens 6142, 6145, 6146, 6147, and 6148 of the Museum of Comparative Zoölogy, all but the last (6148) collected in Massachusetts, form a series fully illustrating the change in color from young to adult, and also the incorrectness of Dr. Coues' conclusions. Without describing each in detail, it may be sufficient to say, that of this series No. 6147 most nearly approaches Dr. Coues' type of *L. Smithsonianus*, but differs from it in the great development of the subapical white spot of the second primary of the right wing, which many times exceeds in size the corresponding spot in the left wing. No. 6148 is a specimen in unusually high plumage, taken at Beaufort, N. C., March 30, and is also of unusually large size. This differs from the others, and also from the diagnosis of *L.* "*Smithsonianus*," in the great extent of the subapical white spot on the first primary, which is one and three fourths inches long and barely separated by a narrow black line from the white tip, and by the large size of the subapical white spot on the inner vane of the second, which is three fourths of an inch by half an inch in extent, instead of being "*entirely absent or a mere speck.*"

Reviewing briefly Dr. Coues' four "tangible differences" between the American and European birds: — 1st, that of larger size; 2d, the larger, longer, and more robust bill; 3d, the greater length and stoutness of the tarsus, (the 2d and 3d distinctions being only more amplified expressions of the first) — we find, he says, after previously admitting that in general color and relative proportion of certain parts there is no appreciable difference, that "the preceding differences, though marked, I should not consider, in absence of other distinctive features, as of specific value. The following discrepancies," he adds, "I find it impossible not to regard as conclusive" they are as follows: —

"4th. In the European bird, when adult, the first primary has a white terminal space just about two inches long. (*This is precisely as in* californicus, *the similarity being further heightened by the fact that in young birds there is a narrow transverse bar, which gradually resolves itself into two small spots, or scallops, and finally disappears*). The second primary has a rounded white spot about three fourths of an inch in diameter, invading both vanes, but divided into two by the black shaft. In the American bird the first primary has a rounded white spot (of much the same size and character as that on the *second* primary of the European bird) entirely distinct and separated from the white apex, which is very small. *The second primary has no white subterminal spot; or if one is present (which is rarely the case in very old birds), it is exceedingly small.*

"Now it may be urged," Dr. Coues continues, "that these differences have been noted, but disregarded as of no value, the nature of the terminal markings on the wings of gulls being considered notoriously inconstant. There is in the Smithsonian Collection perhaps the most extensive series of American Herring Gulls ever brought together. *In no single specimen of the series have I ever observed the slightest approach*

In this list only those families which are more or less peculiarly represented here have received special notice; several have been wholly passed over, on account of the incompleteness of the observations and from there being nothing of special interest to present, the species observed being those of known wide distribution.

to the large white apical space on the first primary which exists in the European bird; constantly, so far as I have opportunities for judging. While the bird is undergoing the changes incident to its arriving at maturity, there are great and indeed endless variations in the precise character of the primaries. All, however, uniformly tend towards the same result, and in fully adult birds *these characters are constant*."

In respect to the variation in size between American and European birds alluded to, "amounting to nearly two inches" in the length of the wing, "and in none is it," be says, "less than half an inch," (see Dr. Coues' "1st" difference,) I have found a difference in a series of *twenty Massachusetts birds fully as great;* between the two extremes it *exceeded* two inches in the length of the wing, while one specimen from the Atlantic coast of Europe is hardly so large as the average. The stoutness of the bill, as well as its form, vary correspondingly, and in respect to the angle especially, which, as the whole bill thickens with age, gradually becomes less acute, or has a less "pointed and well-defined apex. (See Dr. Coues' distinction "2d.")

In respect to the character of the markings of the primaries, there are two specimens in the La Fresnaye collection of the Boston Society of Natural History, labelled "*Larus argentatus*," the one from the Mediterranean and the other undoubtedly from the Atlantic coast of Europe, which, with the Museum of Comparative Zoölogy specimens, complete the series of gradation between the typical *L. Smithsonianus* Coues and the *L. argentatus* Coues. One has the colors of the wing assumed to characterize invariably the European, and the other is identical in this respect with the Beaufort specimen in the Museum of Comparative Zoölogy, in which (the European) the subterminal white spot is separated from the terminal by a band of black. In this connection particular attention is requested to the sentences we have italicized in the above quotations, and to the preceding description of the American specimens in the Museum of Comparative Zoölogy. The "notorious inconstancy" in the terminal markings of the wing above referred to as having been generally received as a fact, our own experience seems fully to confirm. Yet there is still an evident law of change, which is simply an increase in the size of the white markings of the wings, and in the general purity of color, with the increase of age, with a like modification in the thickness of the bill, and the outline below of the lower mandible; old birds having the largest amount of white on the first primary, and a subterminal white spot on the second, often of considerable size, while these decrease in size in younger specimens till we miss them entirely in birds of the first and second years. The black band across the tips of the primaries also increases, especially on the inner ones; when first appearing being present on only the five or six outer, and afterwards reaching the seventh, and more rarely the eighth. Dr. Coues' opinion that the subterminal white spots on the second primaries are characteristic of immature birds, and are of particularly rare occurrence "in very old birds" (see his "4th" difference), is wholly at variance with the general law apparent in the changes in markings of this character; at least I am quite unable to recall a single corroborative case. From his description of them, the four European specimens examined by Dr. Coues were evidently very mature birds.

If the differences indicated by Dr. Coues' diagnoses of the American and European Herring Gulls had been constant, no one would doubtless question their claims to specific diversity; but among birds presenting variable characters, as in the present case, it seems to me we cannot be too fully on our guard in allowing such characters weight till we fully know the amount of this variability, and have, if possible, obtained some clew to its cause and laws of change. While sincerely regretting that my convictions in this case lead me to expressions of opinion at variance with those of so thorough and careful an ornithologist as my friend Dr. Coues, they are of course made only in a spirit of cordiality, and with the sole desire of advancing truth.

I can hardly dismiss the subject without alluding to other queries which my study of the Gulls has developed, one of which is as to whether *L. californicus* Swain. is really distinct from *L. argentatus* Brünn. or is based on very mature individuals of the latter. In respect to their distribution, we find *L. argentatus* (*Smithsonianus* Coues) ranging across the continent; *L. californicus*, originally described by Lawrence from California, comes not only from the Pacific Coast but from the interior of North America, and from Arctic America generally; while the Beaufort specimen mentioned above comes very near, if it be not actually identical with it. *Larus argentatoides* of both Bonaparte and Richardson is, as Dr. Coues observes, undoubtedly to be referred to it; *L. argentatoides* of Brehm seems alike referable to it, if we ignore its European locality; otherwise we must also recognize this form from both continents. Bonaparte also gives it as "common near New York and Philadelphia." The original specimen of *californicus* as described by Coues (l. c. p. 301), accords in the character of the wing-markings with my specimen from Beaufort. The resolving of the black bar on the first primary in the series of specimens of *californicus* into "two little spots, then into a slight indentation at the edge of the feather, which finally disappears altogether, leaving the apex of the first primary purely and uninterruptedly white for nearly two inches," as mentioned by Dr. Coues, is not only suggestive of its relationship to the true *argentatus*, but of the inconstancy of this character in a closely allied but supposed distinct species, which is taken as the basis for the separation of "*Smithsonianus*" from *argentatus*. Upon the relationship of *californicus* to the European *argentatus* we find Dr. Coues himself saying, "If it be an error to refer the *argentatoides* of Richardson to the *californicus*, or, in other words, if there be a true Herring Gull in the north with flesh-colored legs, *I do not know by what characters it could be separated from the true European* argentatus" (l. c. 302). The different color of the

It may be added that among the rapacious birds *Pandion* "*carolinensis* Bon." is rather common; that *Nauclerus furcatus* has been several times taken near Chicago; and that *Cathartes aura* is known as a rather infrequent visitor. As far north, however, as the Kalamazoo River in Michigan, I found this species well known, where in summer it is said to be quite common.

III. Richmond, Wayne County, Indiana.

To render the following list more complete than my own opportunities for observation allowed, I have added several species on the authority of Dr. Haymond, who some time since published a list of one hundred and forty-seven species of birds observed by him in southeastern Indiana.[1] His observations appear to have been made on the White Water

legs, as indicated by collectors' labels, of *californicus*, is by far too variable a character to have alone much weight. There seems then, in short, but little reason why *californicus*, as well as *Smithsonianus*, should not be referred to *argentatus*; "*californicus*" being perhaps more generally found in the higher latitudes and representing the most perfect condition of the American *argentatus*, "*Smithsonianus*" forming the southern race, with a larger proportion of immature birds; as we have good data for supposing that, in general, fully mature birds prefer a locality more northern than do the younger representatives of the species. With this view the argument based on the supposed southern distribution of "*Smithsonianus*" in favor of its distinctness is unfounded.

Since the above was written I have received a mature specimen of the Herring Gull from my friend Mr. C. J. Maynard, killed at Ipswich, Mass., early in the fall, that in every way corresponds with the typical *L. argentatus* of Coues, or with the more mature European birds. The first primary is white for about two inches, the subterminal black bar being entirely obsolete; the second has the subterminal white spot *entirely covering both vanes* for the space of more than an inch.

A series of six mature specimens in alcohol, in the Museum of Comparative Zoölogy, presents the following gradation: No. 985, from Lake Winnipeg, collected by Mr. S. H. Scudder, has no white subterminal spot on the second primary, and a wide black bar separates the apical white spot from the subterminal in the first primary; another, from Grand Menan, is like this, except in having a very small subterminal white spot on the second primary; No. 2633, from Malden, Mass., has the second primary like the last, but the separating black bar on the first is nearly obsolete; No. 244, from the Mingan Islands, has the white spot nearly covering both vanes of the second primary, but on the first the separating black bar is still distinct. Other specimens from those already mentioned show the same inconstancy of marking of the first and second primaries, with a more or less decided approach to what has been assumed as exclusively the European style. To sum up the facts in a general statement, less than a third of the mature American birds examined have the markings of the first and second primaries according with Dr. Coues' diagnosis; nearly another third have them like, or very nearly like, his diagnosis of the European; the remainder being intermediate; of the two European specimens examined, one is like the average of American specimens, while the other is fully matched by several of my American birds, which in every way bear marks of being either in very high plumage, or of being very old birds.

[In relation to the variability of the markings of the wings of gulls, the following important testimony of Audubon, in his account of the Laughing Gull (*Chroicocephalus atricilla*; Birds of America, VII, 137), escaped my notice till after tho preceding had been placed in the hands of the printer.

"As to the white spots on the extremities of the primary quills of birds of this family, I would have you, reader, never to consider them as affording essential characters. Nay, if you neglect them altogether, you will save yourself much trouble, *as they will only mislead you by their interminable changes*, [the italicising in these quotations from Audubon is entirely my own] and you may see that the spots on one wing are sometimes different in size and number from those on the other wing of the same specimen. If all this be correct, as I assure you it must be, being the result of numberless observations made in the course of many years, *in the very places of resort* of our different gulls, will you not agree with me, reader, that the difficulty of distinguishing two very nearly allied species must be almost insuperable *when one has nothing but a few dried skins* for objects of observation and comparison?"

In his description of the Herring Gull (*Larus argentatus* Brünn.), he further observes (*Ib.*, p. 169): "From the examination of individuals of this species, it would appear that little reliance can be placed on the markings of the quills as affording specific character. Four undoubted specimens of *Larus argentatus* now before me have a white spot, varying in length from one to two inches, and including both webs, near the end of the first quill. One has no spot on the second quill; another has a white spot on both webs of the second quill of one wing, and a smaller spot on part of the inner web of the same quill on the other wing; the third has a very small spot on part of the inner web of the same quill of both wings; the fourth has a large circular spot on the inner web of that quill, also in both wings."

Probably no naturalist has ever had so favorable opportunities for observing our various species of gulls in life, and of studying them from fresh specimens, as Audubon. His testimony on this point is hence of the highest importance.]

[1] *Birds of Southeastern Indiana.* By Rufus Haymond, M. D., Proc. of the Philadelphia Academy of Natural Sciences, November, 1856.

River, not many miles below Richmond, sufficiently near our point of observation for all practical purposes. The list of Dr. Haymond, though very valuable, is evidently quite incomplete. Fifty-eight species only are noted particularly as breeding. Our present list numbers seventy-three, including several not mentioned by Dr. Haymond; some ten or twelve, however, are included on his authority. Although so incomplete, it still affords some data of value on the general character of the locality. Compared with Northern Illinois, Western New York, or New England, it has quite a southern aspect, and undoubtedly lies not far from the southern boundary of the Alleghanian fauna. Leaving Chicago about the close of May, its more southern character very forcibly struck me, in the more advanced state of the vegetation, and in the occupations of the birds. While at Chicago and vicinity, the cherry, plum, and pear-trees were but just coming into flower, and the greater part of the indigenous trees were still destitute of foliage, the leaves being only conspicuous in such early leafing species as the *Populus tremuloides,* and the migration of the warblers and some other birds was just at its greatest height, I found twenty-four hours later, in south-eastern Indiana, the forests in full leaf, even apple orchards with the fruit already set, and all the birds settled for the summer, and most of them more or less advanced in incubation. The southern character of the locality is more especially indicated by *Cathartes aura* being resident here, and, according to Dr. Haymond, the former abundance of *Conurus carolinensis*

TURDIDÆ.

1. *Turdus migratorius* Linn. Common. Dr. Haymond gives it as resident, but most abundant in winter.

2. *Turdus mustelinus* Gmel. Common. (Haymond.)

3. *Harporhynchus rufus* Cab. Very common.

4. *Galeoscoptes carolinensis* Cab. Very common.

5. *Mimus polyglottus* Boie. "I have seen a few, and heard the notes of a few others, here within the last thirty years." (Haymond.)

SAXICOLIDÆ.

6. *Sialia sialis* Bd. Numerous. According to Haymond is resident the whole year.

SYLVIIDÆ.

7. *Polioptila cœrulea* Sclat. "The most numerous of all the fly-catching tribe." (Haymond.)

PARIDÆ.

8. *Parus atricapillus* Linn. Abundant.

9. *Lophophanes bicolor* Bon. Abundant. Said by Dr. Haymond to be about as numerous as the preceding. Saw six or eight together feeding on the carcass of a dead horse.

TROGLODYTIDÆ.

10. *Troglodytes ædon* Vieill. Abundant.

11. *Thryothorus ludovicianus* Bon. Apparently not rare.

SYLVICOLIDÆ.

12. *Dendrœca æstiva* Bd. Common, and the only species of the family seen.

Hirundinidæ.

13. *Hirundo horreorum* Barton. Abundant.

14. *Petrochelidon lunifrons* Bd. (*Hirundo lunifrons* Say.) Abundant. "This species has been quite numerous since the summer of 1849, when for the first time they built their nests in this county." (Haymond.)

15. *Progne subis* Bd. (*P. purpurea* Boie.) Common.

16. *Cotyle riparia* Boie. Abundant.

Vireonidæ.

17. *Vireosylvia olivacea* Bon. Abundant.

18. *Vireosylvia gilva* Cass. Very common. Had commenced incubation May 28.

19. *Vireo noveboracensis* Bon. "Very numerous." (Haymond.)

Ampelidæ.

20. *Ampelis cedrorum* Bd. Abundant.

Tanagridæ.

21. *Pyranga rubra* Vieill. Common. Said by Haymond to be the only species of *Pyranga* he had observed here.

Fringillidæ.

22. *Chrysomitris tristis* Bon. Abundant.

23. *Poœcetes gramineus* Bd. Very abundant. Next in abundance to *Euspiza americana*, the most numerous species of the family.

24. *Coturniculus passerinus* Bon. Common.

25. *Spizella socialis* Bon. Abundant. June 1st, found a nest of this species containing three eggs, *built in the grass within three or four inches of the ground.*

26. *Melospiza melodia* Bd. Abundant. The only species of *Melospiza* noticed.

27. *Euspiza americana* Bon. Excessively abundant. Sometimes a dozen were observed singing within hearing at the same instant. June 1st, saw them carrying materials for their nests.

28. *Hedymeles ludoviciana* Cab. Common.

29. *Cardinalis virginianus* Bon. Very common.

30. *Cyanospiza cyanea* Bon. Common.

31. *Pipilo erythrophthalmus* Vieill. Abundant.

Icteridæ.

32. *Molothrus pecoris* Swain. Common.

33. *Agelæus phœniceus* Vieill. Common.

34. *Sturnella magna* Swain. Abundant.

35. *Icterus spurius* Bon. Common.

36. *Icterus Baltimore* Daud. Common. Perhaps rather less so than the preceding; certainly much less abundant than in New England. Both species of *Icteri* building nests May 25th to 30th.

37. *Quiscalus versicolor* Vieill. Common. According to Haymond, raises its single brood early in the season, and both young and old go north about the middle of June, and are not seen again till fall.

The Bobolink (*Dolichonyx oryzivorus* Sw.) I did not see. Dr. Haymond says it does not breed here, all going farther north.

CORVIDÆ.

38. *Corvus americanus* Aud. Common. Young fully fledged June 1st.

39. *Corvus corax* Linn. According to Dr. Haymond was "formerly very numerous here, but is now (1856) exceedingly rare."

40. *Cyanura cristata* Swain. Abundant, and as unsuspicious as the Cat Bird (*Galeoscoptes carolinensis*), nesting in the shrubbery of the town. Saw a nest of these birds in a bunch of lilacs under a window on one of the principal streets of Richmond.

TYRANNIDÆ.

41. *Tyrannus carolinensis* Bd. Common.
42. *Myiarchus crinitus* Cab. Abundant.
43. *Sayornis fuscus* Bd. Common.
44. *Contopus virens* Cab. Common.

ALCEDINIDÆ.

45. *Ceryle alcyon* Boie. Common.

CAPRIMULGIDÆ.

46. *Antrostomus carolinensis* Bon. Abundant.

Dr. Haymond says that the Night Hawk (*Chordeiles popetue* Bd.) does not breed here, though seen in its migrations. I did not observe it.

CYPSELIDÆ.

47. *Chætura pelasgia* Steph. Very abundant.

TROCHILIDÆ.

48. *Trochilus colubris* Linn. Abundant.

CUCULIDÆ.

49. *Coccygus americanus* Bon. Common. (Haymond.)

PICIDÆ.

50. *Picus villosus* Linn. Common.
51. *Picus pubescens* Linn. Common.
52. *Melanerpes erythrocephalus* Swain. Excessively abundant. The most conspicuous species of bird.
53. *Centurus carolinus* Bon. Rather common.
54. *Colaptes auratus* Swain. Abundant.

PSITTACIDÆ.

55. *Conurus carolinensis* Kuhl. Says Dr. Haymond in 1856, "This bird was formerly very numerous along White Water River. Several years have elapsed since any of them have been seen."

STRIGIDÆ.

56. *Bubo virginianus* Bon. Common.

57. *Scops asio* Bon. Common.

58. *Syrnium nebulosum* Gray. "Quite numerous in all the timbered country, though by no means so numerous as they formerly were." (Haymond).

Falconidæ.

59. *Falco sparverius* Linn. Common. (Haymond).

60. *Buteo borealis* Vieill. Common.

61. *Circus hudsonius* Vieill. Common.

62. *Nauclerus furcatus* Vig. Rare. (Haymond).

Vulturidæ.

63. *Cathartes aura* Ill. "Numerous throughout the county *at all seasons of the year*." (Haymond).

Columbidæ.

64. *Zenædura carolinensis* Bon. Common.

The Pigeon (*Ectopistes migratoria*), though once abundant, is now said to occur rarely in very large numbers.

Meleagridæ.

65. *Meleagris gallopavo* Linn. "Formerly very numerous, they have now become almost extinct in this section. A very few, however, still linger amongst us." (Haymond).

Tetraonidæ.

66. *Bonasa umbellus* Steph. Common.

I could not learn that *Cupidonia cupido* had ever existed here.

Perdicidæ.

67. *Ortyx virginianus* Bon. Abundant.

Charadriidæ.

68. *Ægialitis vociferus* Cass. Common.

Scolopacidæ.

69. *Tringoides macularius* Gray. Common.

Ardeidæ.

70. *Ardea herodias* Linn. "Quite abundant during the warmer seasons of the year." (Haymond).

71. *Butorides virescens* Bon. Common. "Very numerous along all our streams." (Haymond).

Anatidæ.

72. *Aix sponsa* Boie. "They breed here occasionally in the hollow trees." (Haymond.) Probably the only species of *Anatidæ* that does breed here.

Published December, 1868.

XIV. *Notes on* Hesperomannia, *a new Genus of Hawaiian Compositæ. By* William T. Brigham.

Read May 6, 1868.

Dr. ASA GRAY, who named this new genus, has given the following generic characters.[1]

Hesperomannia. Nov. Gen. *Mutisiacearum.*

"Capitulum homogamum, multiflorum et æqualiflorum, discoideum, floribus hermaphroditis. Involucrum campanulato-turbinatum, multiseriale; squamis chartaceo-rigidis obsolete nervatis, mucronato-acutis, interioribus lineari-lanceolatis, exterioribus sensim brevioribus. Receptaculum planum nudum. Corollæ subcoriaceæ, angustæ, subregularis (leviter bilabiatæ, $\frac{2}{3}$, extus intusque glabræ, tubo quinque-nervi), laciniis longis linearibus erectis. Filamenta imo tubo corollæ inserta, e fauce exserta: antheræ lineares, brevissime caudatæ, caudis truncatis ultra articulum haud productis. Stylus filiformis, ramis brevissimis angustis acutiusculis. Achenium oblongo-lineare, angulatum, erostre, glabrum. Pappus multiserialis, setis rigidulis scabris.—Arbuscula inermis, glaber; foliis obovato-oblongis subserratis penninerviis breviter petiolatis ad apices ramorum brevium confertis; capitulis terminalibus subumbellatis brevipedunculatis ca *Chuquiragæ insignis* æmulantibus; floribus flavis."

Hesperomannia arborescens. Gray. The only known species of this genus was found by Mr. Horace Mann on the summit of Lanai, almost in the centre of the Hawaiian Group, longitude 157° W., latitude 20° 45′ N., at an altitude of about two thousand feet. A single tree was seen, but from the nature of the country, it is not impossible that many more grow in the immediate neighborhood hitherto unobserved. I however looked for it on Molokaì, the nearest island, separated from Lanai by a narrow strait, and quite similar, on its southwestern end, in soil and climate, but without success. It is probably confined to Lanai.

The specimen found was a small tree some twenty feet high, and divaricately branched, bearing several flower-heads at the ends of the branches. Leaves 3 to 5 inches long, 1 to 1.5 inches wide, clustered near the ends of the branches which are rough; the flower-heads are from 1.5 to 2 inches in diameter, with bright yellow flowers and tawny pappus.

The genus falls into the group *Flotowieæ* of Weddell's arrangement of the *Mutisiaceæ*, and is closely allied to the common Andine genera *Chuquiraga* and *Doniophyton*, and on the other hand to the Cuban and Brazilian genera *Stiftia* and *Anastraphia.* This is not only the only known Labiatiflora on the Hawaiian Islands, but also the only one from any of the proper Pacific Islands. It adds another to the very small company of arborescent compositæ.

Dr. Gray has named this genus in honor of its discoverer, my friend and companion in Hawaiian exploration, Mr. Horace Mann, whose discoveries of Hawaiian plants amount to nearly ten per centum of the whole Phænogamous Flora as yet described. As the name *Mannia* had already been bestowed upon a genus of *Simarubeæ* in commemoration of the botanical labors of Mr. Gustavus Mann in Tropical Africa, the word is compounded by a distinguishing prefix. It may be added, that seeds of Hesperomannia have been planted in Honolulu, and plants grown from them.

[1] Proceedings of the American Academy of Arts and Sciences, Vol. VI, p. 554.

Of the arborescent compositæ, which exceed twenty-five feet, only four are known; — *Vernonia celebica, V. Blumeana, Synchodendron ramiflorum,* which attain fifty or sixty feet, and *Melanodendron integrifolium,* of which the height is not known, but the trunk is five or six feet in circumference. Those compositæ, which are about twenty feet high, are represented principally by the following list, which is, however, by no means complete: —

Brachyglottis,	New Zealand.
Microglossa altissima,	Madagascar.
Commidendron (5 species),	St. Helena.
Petrobium,	" "
Lachanodes (3 species),	" "
Robinsonia (4 species),	Juan Fernandez.
Rea (7 species),	" "
Raillardia (4 species),	Hawaiian Islands.
Hesperomannia,	" "

The relation this genus bears to the other Hawaiian Compositæ may be seen from the following statistics: —

Genera,	24	Endemic genera,	6	Genera of endemic species,	8.
Species,	59	" species,	46		

Of the Phænogamous Flora the Compositæ form one tenth of the genera and about the same proportion of the species. The largest number of species to a genus is eleven, and the genera of more than one species are represented thus: —

† Raillardia,	11	Bidens,	4
Lipochæta,	10	† Dubautia,	3
Vittadinia,	7	† Argyroxiphium.	2
† Campylotheca,	5		

These seven genera represent forty-two species, and the four endemic genera, marked †, twenty-one species. The six endemic genera, Raillardia, Campylotheca, Dubautia, Argyroxiphium, Wilkesia and Hesperomannia, have twenty-three species, or an average of nearly four. Ten species belonging to nine genera have probably been introduced in recent times.

Explanation of Plate XX.

a Corolla. *b* Achenium. *c* Corolla unfolded. *d* Stamen. *e* Pistil.

Published December, 1868.

XV. *Notes on Alsinidendron, Platydesma, and Brighamia, New Genera of Hawaiian Plants; with an Analysis of the Hawaiian Flora.* By Horace Mann.

Read December 2, 1868.

One of the new genera described in the "Enumeration of Hawaiian Plants," published by the late Mr. Horace Mann, and named in his honor, Hesperomannia, has been figured in these Memoirs, Plate XX, and the three here presented were carefully examined by Mr. Mann; and from his notes, the following descriptions are mainly drawn. The Plates are from drawings by Mr. W. T. Brigham.

CARYOPHYLLACEÆ.

Alsinidendron *H. Mann.* Plate XXI.

Calyx quadripartitus, sepalis decussatim imbricatis ovalibus subcarnosis albidis etiam sub anthesi conniventibus, raro cum quinto minimo interno. Petala et staminodia nulla. Stamina decem, margini disci tenuissimæ basi calycis accreti inserta: filamenta filiformia: antheræ lineari-oblongæ, utrinque emarginatæ. Ovarium uniloculare; ovulis plurimis columellæ centrali affixis: styli quatuor ad septem, breviter filiformes, apice intus stigmatosi. Capsula quatuor ad septem-valvis, polysperma. Semina estrophiolata. Frutex Hawaiiensis, orgyalis, fere glaber; ramis foliosis; foliis oppositis amplis ovatis ovalibusque cuspidato-acuminatis basi in petiolum subito angustatis eximie trinervatis subeveniis; cymis plurifloribus pedunculatis ex axillis superioribus, floribus subglobosis in pedicellis filiformibus pendulis.

Alsinidendron trinerve H. Mann. Proc. Bost. Soc. Nat. Hist., Vol. X, p. 312.

Growing on the Kaàla Mountains, Oáhu, at an elevation of about two thousand feet, — a glabrous branching shrub about six feet high. Leaves three or four inches long, and one and a half to two inches wide, of a somewhat chartaceous texture, oval or ovate, cuspidate-acuminate, tapering abruptly at the base into a margined petiole about an inch long, and with three strong ribs running from the base to the very apex. Cymes from the axils of the upper leaves, on peduncles an inch or more long. Flowers pendulous from the ends of long (3–8 lines) capillary pedicels, somewhat globose in shape, a little truncated at the base, and of a light or whitish color. Sepals four (rarely with a minute internal fifth), about four lines long, a little fleshy at the base, but with thinner margins and apex, closely imbricated, the two outer completely enclosing the two inner in the bud. Petals and staminodia none, stamens ten,— shorter than the calyx; the filaments arising from the margin of a thin perigynous disk, and about as long as the oblong-linear emarginate anthers, which are erect and affixed by a deeply notched base. Ovary ovoid; styles short, four to seven. Capsule membranaceous (only the immature seen), and probably not opening by valves. Seeds numerous, borne on a central placenta, roughened by longitudinal lines of blunt tubercles. (Mann and Brigham, Coll. 582. Also Hillebrand, fide Oliver in litt.)

RUTACÆ.

Platydesma *H. Mann.* Plate XXII.

Flores hermaphroditi. Calyx quadrisepalus, persistens, valde imbricatus; sepalis rotundis, exterioribus majoribus interiora æstivatione includentibus. Petala quatuor, æstivatione late convoluto-imbricata vel convoluta, ampla, obovata, apice recurva. Discus planus, leviter quatuor-lobus. Stamina octo, disco inserta, infra medium monadelpha; filamentis nudis ovatis seu ovato-lanceolatis crassis; antheræ sagittatæ, facei interiori infra apicem filamenti adnatæ. Ovarium quadri-partitum; stylus centralis, stigmate quadrilobo; ovula in loculis quinque, amphitropa. Cocci erecti, omnino discreti, subsucculenti, abortu sæpissime di-spermi, endocarpio tenui cartilagineo. Embryo, . . . (a nobis non visa). Arbuscula Hawaiiensis, fere glabra, graveolens. Folia opposita, ampla, simplicia, lanceolata vel obovato-lanceolata, obtusa vel acuminata, petiolata. Cymæ axillares pauciflore, pedicellis bi-bracteolatis, Flores magni, albi.

Platydesma campanulata H. Mann. Proc. Bost. Soc. Nat. Hist., Vol. X, p. 317.

A tree twenty-five or thirty feet in height, with a spreading crown, and a trunk eight or ten inches in diameter, nearly glabrous; the younger branches and leafy shoots of a light color, or when quite young greenish, striped with narrow ridges and depressions, exhaling a strong terebinthine odor when cut or bruised. Leaves varying in size on different parts of the tree, from three to fourteen inches long, by one to four or five wide, lanceolate, or more usually obovate-lanceolate, obtuse or acuminate, dark green above, and lighter beneath, tapering at the base, of a not very thick coriaceous texture, pinnately veined (six to eighteen pairs of veins); the veins divaricating after reaching about three fourths of the distance to the margin, not uniting to form a distinct intra-marginal vein, and not strongly reticulated; the leaves very copiously punctate with innumerable small raised glandular dots appearing black by reflected light; the petioles one half to two inches long. Peduncles about equalling the petioles in length, bearing ovate-subulate bracts. Cyme three- to five-flowered. Pedicels bracteolate, two or three lines long. Flowers hermaphrodite, nine to ten lines long by six to seven lines in diameter, campanulate. Sepals four, four or five lines long, decussatingly imbricated, the two outer longer and much thicker ones enclosing the two inner in the bud, clothed with a minute sericeous pubescence extending down on to the pedicels. Petals four, alternate with the sepals, in æstivation strongly imbricated or often truly convolute, inserted under the disk, eight to nine lines long, obovate, thick and fleshy, white, minutely sericeous, bearded on the margins, with the somewhat spreading and recurved tips apiculate. Stamens eight, nearly as long as the petals, inserted on the margin of the thin hypogynous disk; the much dilated filaments monadelphous to the middle; the sagittate introrsely dehiscent anthers wholly adnate to their interior face, and about two lines long. Ovary globular, the four rounded-triangular carpels joined only by the central columnar style, which is four times their length. Stigma terminal, entire, slightly four-grooved. Ovules five in each cell, collateral and superposed, hemitropous. Fruit consisting of four coriaceous, erect, distinct cocci, eight or nine lines long, and three or four in diameter, lined with a hard, smooth, crustaceous endocarp, and half enclosed by the persistent cup-shaped calyx; usually ripening two seeds, which very much resemble those of *Pelea*. The embryo was not seen. (Mann and Brigham, Coll. 94.)

My friend and companion, Mr. W. T. Brigham, in crossing a dense thicket on the mountains just above Honolulu, found a tree of much the size and appearance of this species, but with much larger and more glabrous leaves, and much larger blossoms, nearly three quarters of an inch in diameter; only one tree was seen, and unfortunately the specimens were ruined in climbing out of the tangled mass of *Freycinetia*, which was nearly impassable in the rain and approaching darkness. Although we both twice returned as nearly as possible to the spot, such was the nature of the vegetation that we could not rediscover the desired tree. It was much more beautiful, and if not a distinct species, was yet a remarkable variety.

P. campanulata is common in the locality mentioned, or between the ridge of Ualakáa and the summit of Konahuanùi in the thickly wooded depressions at middle height, and takes to some extent the place of *Melicope* so common on other islands.

LOBELIACEÆ.

Brighamia *A. Gray.* Plate XXIII.

Calyx tubo oblongo eximie decem-costato, dentibus parvulis. Corolla hypocraterimorpha; tubo prælongo fere recto antice sinubus duobus profundius fisso; lobis ovato-oblongis æqualiter patentibus consimilibus, nisi duobus anticis longiter unguiculatis. Columna staminea corollæ, tubo infra medium (postice altius) adnata; synanthera subinclusa apice recurvo barbata. Ovarium biloculare. Stigma bilobum, nudum. Capsula primum carnosa, loculis demum rimis duabus longitudinaliter dehiscentibus. Semina oblonga; testa tenuiter crustacea læviuscula; embryo rectus albumine oleoso brevior. Arbuscula Hawaiiensis, carnosa, glabra; caule orgyali simplicissimo folia obovata subintegerrima creberrime quasi capitatim conferta gerente; pedunculis axillaribus folio brevioribus apice racemoso-paucifloris; floribus pedicello recto haud resupinatis albis.

Brighamia insignis A. Gray. Proc. Amer. Acad. Arts and Sc., Vol. VII, p. 185.

Stem simple, five to fifteen feet high, naked except at top. Leaf scars mostly obliterated at the base where the circumference is often two feet. Leaves six to ten inches long, simple, obovate, more or less cup-shaped, with a short fleshy petiole extending through the leaf as a prominent midrib, collected in a sort of head at the summit of the stem, in color light, vivid green. Peduncles stout and fleshy, three to five inches long; the thick ascending pedicels half an inch or an inch long; bracts deciduous. Calyx-teeth much shorter than the tube, oblong-linear, slightly accrescent and persistent in the ripe fruit. Corolla showy, slightly fragrant, white with a tinge of cream-color, greenish in bud; the rather slender tube four to six inches long, slightly incurved; the five lobes when expanded about an inch long, thickish, valvate in æstivation, and flat so as to give a pentagonal section to the bud; the pointed tips inflexed, in size and position nearly equal and regular as in *Isotoma*, but the two anterior lobes separated from each other and from the lateral ones by sinuses forming narrow claws of nearly the same length as the lobe. The anther tube is half an inch long, scarcely projecting beyond the cleft of the corolla, straight with the apex abruptly curved towards the upper side of the flower, and tipped with a uniform tuft of beard, otherwise glabrous. Stigma neither bearded nor indusiate, of two small and flat rounded lobes. Ovary acutely and nearly equably ten-ribbed. Fruit capsular, three fourths of an inch long, fleshy-coriaceous, ten-ribbed, green when ripe, with a purplish tinge at the base of the persistent calyx-teeth, white inside; each cell opening by two equi-distant, longitudinal, intercostal chinks or clefts extending from just below the apex to the base. Seeds very numerous, half a line long. Described by Dr. Gray from a specimen collected by Jules Remy, communicated by the Paris Museum, and from specimens collected by William T. Brigham, Esq., including fruit and flowers in alcohol.

Dr. Gray remarks that the resemblance of this plant to *Isotoma* is mainly in the great length and general form of the corolla, but its true relationship is evidently with the unfortunately little-known *Sclerotheca arborea.* D C. (*Lobelia arborea*, Forst.) of Tahiti. In that, however, so far as is made out, the corolla is no longer than the foliaceous calyx-lobes, and cleft to the base, and the capsule opens at the vertex by two round pores. The one-flowered peduncle is of small moment, as it is bibracteolate.

Mr. Brigham found this very interesting lobeliaceous plant on the side of steep, rocky cliffs near Halàwa, on the eastern end of the island of Molokaì. Remy's specimens were marked "Kauaì or Niihau," and the former island is certainly its habitat, while in all probability it is not found on Oáhu, the intervening island. The juice of the stem is rather watery, and shows none of the glutinous, milky exudation which is so general with the other Hawaiian Lobeliaceæ.

Statistics and Geographical Range of Hawaiian Plants.

The Hawaiian Islands have a surface of about 4000 square miles, situated just within the tropics, and more than one thousand miles from any other land except a few rocks lying to the northwest, bare of vegetation, and inhabited by sea-fowl and seals. On this area, which includes an excessively dry and hot, a very wet and very hot, and from these every other variety to a very dry and very cold climate, is found a Flora of 620 species of flowering plants[1] and ferns, of which the former comprise 485 species, the latter 135; the mosses, lichens, and algæ being left out of consideration as too little known.

Of the 554 flowering plants, including 69 species supposed or known to be introduced, 479 species belong to the Dicotyledonæ, and the remaining 75 to the Monocotyledonæ, in the proportion of nearly 100 to 15. These 554 flowering plants are divided among 253 genera, giving to each genus on an average 2.58 species. There are 87 natural orders of flowering plants represented in the group. Of the 554 flowering plants 377 are peculiar to the Group, while 42 are of recent and 27 of supposed aboriginal introduction, giving the proportion of endemic species 68.05, of introduced (recent) species, 12.46.

Of the 253 genera 39 are peculiar, and these 39 genera are represented by 151 species or 3.94 species to a genus while the whole flora has but 2.58 species to each genus; thus showing the important part which these genera take in constituting the whole phænogamous flora.

Among the genera not peculiar to the islands, there are sixteen, of which the species belong to a distinct group in the genus or which are most largely represented in the South Pacific islands and Australia, or on the Hawaiian Islands themselves.

Geranium, very peculiar species.
Melicope, either to be reduced to *Pelea*, or if not, entirely Australasian.
Pittosporum, largely Australasian.
Coprosma, a marked New Zealand type.
Acacia, an Australian phyllodinous species.
Gouldia, one other species in Pacific.
Vittadinia, New Zealand and Australia.
Lipochæta, mostly Hawaiian, a few in Mexico.
Scævola, mostly in South Seas and Australasia.
Lobelia, species very peculiar.
Cyrtandra, represented in the South Seas and Moluccas: large genus in the Hawaiian Islands.
Cyathodes, Australasian.
Wickstrœmia, many species Hawaiian, represented in South Seas and Australasia.

[1] Omitting *Gramineæ* which have not yet been fully studied.

Santalum, Western Pacific.
Exocarpus, Australasia and Moluccas.
Astelia, " " "

These sixteen genera comprise 76 species or 4.75 to a genus, thus taking an important place in the flora. All the species of the following families are peculiar to the group, omitting of course species known to be introduced.

Ranunculaceæ.	— Celastraceæ.	Solanaceæ.
— Menispermaceæ.	— Saxifragaceæ.	Labiatæ.
Cruciferæ.	— Halorageæ.	— Myoporinæ.
Violaceæ.	— Begoniaceæ.	— Hydrophyllaceæ.
— Bixaceæ.	Araliaceæ.	— Gentianaceæ.
Pittosporaceæ.	Compositæ.	Loganiaceæ.
Caryophyllaceæ.	Lobeliaceæ.	Apocynaceæ.
Portulacaceæ.	Ericaceæ.	— Oleaceæ.
— Camelliaceæ.	— Ebenaceæ.	Santalaceæ.
— Tiliaceæ.	— Sapotaceæ.	— Lauraceæ.
Geraniaceæ.	Myrsinaceæ.	Palmeæ.
Rutaceæ.	Plantaginaceæ.	Smilacinæ.
— Aquifoliaceæ.	Gesneriaceæ.	Juncaceæ.

Of these, sixteen (marked thus —) are represented by a single species, and the remaining twenty-four families comprise 220 species or 9.16 species to each genus. The following families are represented by five or more species:

Violaceæ	6	Myrtaceæ	6	Labiatæ	27
Caryophyllaceæ	14	Cucurbitaceæ	5	Convolvulaceæ	12
Malvaceæ	12	Araliaceæ	8	Solanaceæ	9
Geraniaceæ	5	Rubiaceæ	33	Chenopodiaceæ	5
Rutaceæ	17	Loganiaceæ	5	Amarantaceæ	9
Rhamnaceæ	5	Compositæ	47	Thymelaceæ	6
Pittosporaceæ	6	Lobeliaceæ	35	Piperaceæ	12
Leguminosæ	20	Goodeniaceæ	6	Urticaceæ	13
Rosaceæ	5	Gesneriaceæ	14	Cyperaceæ	39

Those species belonging to families which are not represented by five or more species, are but ninety-two, belonging to fifty-six families, less than two species to each family on an average, while the families in the above list average 14 species each.

Species peculiar to the Hawaiian Islands:

Ranunculus hawaiiensis Gray.
    maviensis Gray.
Nephroica Ferrandiana Gray.
Lepidium oahuense Cham. & Schlect.
    serra H. Mann.
Cleome sandwicensis Gray.
Viola kavaiensis Gray.
    maviensis H. Mann.
    Chamissoniana Ging.
Isodendrion pyrifolium Gray.
    longifolium Gray.
    laurifolium Gray.
Xylosma hawaiiensis Seem.
Pittosporum confertiflorum Gray.
Pittosporum cauliflorum H. Mann.
    terminalioides Planchon.
    spathulatum H. Mann.
    glabrum Hook. & Arn.
    acuminatum H. Mann.
Silene struthioloides Gray.
    lanceolata Gray.
Schiedea Nuttallii Hook.
    diffusa Gray.
    amplexicaulis H. Mann.
    stellarioides H. Mann.
    Menziesii Hook.
    Hookeri Gray.
    ligustrina Cham. & Schlect.

Schiedea spergulina Gray.
Remyi H. Mann.
globosa H. Mann.
viscosa H. Mann.
Alsinidendron trinerve H. Mann.
Portulaca villosa Cham.
sclerocarpa Gray.
Eurya sandwicensis Gray.
Gossypium tomentosum Nutt.
drynarioides Seem.
Hibiscus Youngianus Gaud.
Brackenridgei Gray.
Arnottianus Gray.
———— n. sp.
Abutilon incanum Don.
Menziesii Seem.
Sida sertum Nutt.
Meyeniana Walp.
Waltheria pyrolæfolia Gray.
Elæocarpus bifidus Hook. & Arn.
Geranium multiflorum Gray.
cuneatum Hook.
ovatifolium Gray.
arboreum Gray.
Pelea clusiæfolia Gray.
sapotæfolia H. Mann.
auriculæfolia Gray.
kavaiensis H. Mann.
anisata H. Mann.
oblongifolia Gray.
rotundifolia Gray.
sandwicensis Gray.
volcanica Gray.
Melicope cinerea Gray.
barbigera Gray.
spathulata Gray.
elliptica Gray.
Platydesma campanulata H. Mann.
Zanthoxylum kavaiense Gray.
maviense H. Mann.
(Blackburnia) dipetalum H. Mann.
Byronia sandwicensis Endl.
Perrottetia sandwicensis Gray.
Colubrina oppositifolia Brongn.
Gouania vitifolia Gray.
orbicularis Walp.
Dodonæa eriocarpa Smith.
Sesbania tomentosa Hook. & Arn.
Desmodium sandwicensis E. Meyer.
Vicia Menziesii Spreng.
Erythrina monosperma Gaud.
Canavalia galeata Gaud.
Vigna oahuensis Vogel.
sandwicensis Gray.

Sophora chrysophylla Seem.
Cæsalpinia kavaiensis H. Mann.
Cassia Gaudichaudii Hook. & Arn.
Acacia Koa Gray.
Rubus hawaiiensis Gray.
Macræi Gray.
Acaena exigua Gray.
Broussaisia arguta Gaud.
Gunnera petaloidea Gaud.
Metrosideros rugosa Gray.
macropus Hook. & Arn.
Eugenia sandwicensis Gray.
Sicyos pachycarpus Hook. & Arn.
macrophyllus Gray.
cucumerinus Gray.
microcarpus H. Mann.
Hillebrandia sandwicensis Oliver.
Hedera Gaudichaudii Gray.
platyphylla Gray.
Heptapleurum kavaiense H. Mann.
Dipanax Mannii Seem.
Reynoldsia sandwicensis Gray.
Tetraplasandra hawaiiensis Gray.
Triplasandra oahuensis Gray.
Coprosma rhynchocarpa Gray.
longifolia Gray.
foliosa Gray.
pubens Gray.
Menziesii Gray.
ernodeoides Gray.
Psychotria hexandra H. Mann.
grandiflora H. Mann.
Straussia Kaduana Gray.
Mariniana Gray.
hawaiiensis Gray.
Bobea elatior Gaud.
brevipes Gray.
Guettardella sandwicensis H. Mann.
Gardenia Brighami H. Mann.
Remyi H. Mann.
Gouldia sandwicensis Gray.
Kadua laxiflora H. Mann.
centranthoides Hook. & Arn.
glomerata Hook. & Arn.
cordata Cham. & Schlecht.
Cookiana Cham. & Schlecht.
parvula Gray.
glaucifolia Gray.
Menziesiana Cham. & Schlecht.
acuminata Cham. & Schlecht.
petiolata Gray.
grandis Gray.
Lagenophora maviensis H. Mann.
Aster sandwicensis Gray.

Vittadinia humilis Gray.
tenerrima Gray.
Remyi Gray.
Chamissonis Gray.
consanguinea Gray.
arenaria Gray.
conyzoides Gray.
Coreopsis maviensis Gray.
macrocarpa Gray.
Macræi Gray.
cosmoides Gray.
Menziesii Gray.
micrantha Gray.
Bidens sandwicensis Less.
hawaiiensis Gray.
Lipochæta australis Gray.
subcordata Gray.
calycosa Gray.
lavarum D C.
integrifolia Gray.
succulenta D C.
heterophylla Gray.
tenuifolia Gray.
micrantha Gray.
Remyi Gray.
Argyroxiphium sandwicense D C.
macrocephalum Gray.
Wilkesia gymnoxiphium Gray.
Dubautia plantaginea Gaud.
laxa Hook. & Arn.
paleata Gray.
Raillardia latifolia Gray.
scabra D C.
laxiflora D C.
ciliolata D C.
Hillebrandi H. Mann.
linearis Gaud.
Menziesii Gray.
platyphylla Gray.
arborea Gray.
montana H. Mann.
struthioloides Gray.
Hesperomannia arborescens Gray.
Rollandia lanceolata Gaud.
crispa Gaud.
Humboldtiana Gaud.
Delissea clermontioides Gaud.
coriacea Gray.
obtusa Gray.
hirtella H. Mann.
acuminata Gaud.
angustifolia Presl.
rhytidosperma H. Mann.
arborea H. Mann.
Delissea subcordata Gaud.
undulata Gaud.
platyphylla Gray.
racemosa H. Mann.
calycina Presl.
pinnatifida Presl.
ambigua Presl.
Mannii Brigham.
fissa H. Mann.
pilosa Gray.
asplenifolia H. Mann.
Cyanea aspera Gray.
arborescens H. Mann.
lobata H. Mann.
Grimesiana Gaud.
leptostegia Gray.
tritomantha Gray.
superba Gray.
Clermontia grandiflora Gaud.
parviflora Gaud.
Brighamia insignis Gray.
Lobelia macrostachys Hook. & Arn.
Gaudichaudii D C.
neriifolia Gray.
Scævola coriacea Nutt.
Gaudichaudii Hook. & Arn.
Chamissoniana Gaud.
mollis Hook. & Arn.
glabra Hook. & Arn.
Vaccinium reticulatum Smith.
penduliflorum, Gaud.
Cyathodes imbricata.
Maba sandwicensis D C.
Sapota sandwicensis Gray.
Myrsine Gaudichaudii D C.
Lessertiana D C.
sandwicensis D C.
Lysimachia Hillebrandi Hook.
Plantago princeps Cham. & Schlecht.
pachyphylla Gray.
Cyrtandra cordifolia Gaud.
platyphylla Gray.
Pickeringii Gray.
triflora Gaud.
grandiflora Gaud.
œnobarba H. Mann.
Lessoniana Gaud.
paludosa Gaud.
Garnottiana Gaud.
laxiflora H. Mann.
Macræi Gray.
Menziesii Hook. & Arn.
——— n. sp.
——— n. sp.

Solanum Nelsoni Duval.
  sandwicense Hook. & Arn.
  incompletum Duval.
Lycium sandwicense Gray.
Nothocestrum latifolium Gray.
  longifolium Gray.
  brevifolium Gray.
  subcordatum H. Mann.
Sphacele hastata Gray.
Phyllostegia vestita Benth.
  grandiflora Benth.
  brevidens Gray.
  glabra Benth.
  hirsuta Benth.
  parviflora Benth.
  rosmarinifolia H. Mann.
  stachyoides Gray.
  clavata Benth.
  racemosa Benth.
  haplostachya Gray.
  Hillebrandi H. Mann.
  truncata Gray.
  floribunda Benth.
Stenogyne macrantha Benth.
  rotundifolia Gray.
  cordata Benth.
  sessilis Benth.
  calaminthoides Gray.
  scrophularioides Benth.
  purpurea H. Mann.
  rugosa Benth.
  angustifolia Gray.
  parviflora H. Mann.
  microphylla Benth.
  crenata Gray.
  diffusa Gray.
Myoporum sandwicense Gray.
Nama sandwicense Gray.
Jacquemontia sandwicensis Gray.
Bonamia Menziesii Gray.
Cuscuta sandwichiana Choisy.
Erythæa sabæoides Gray.
Labordea fagræoidea Gaud.
  pallida H. Mann.
  hirtella H. Mann.
  membranacea H. Mann.
  tinifolia Gray.
Alyxia olivæformis Gaud.
Rauwolfia sandwicensis D C.
Ochrosia sandwicensis D C.
  ———— n. sp.
Olea sandwicensis Gray.
Rumex giganteus Ait.
Santalum Freycinetianum Gaud.
Santalum pyrularium Gray.
Exocarpus Gaudichaudii D C.
Oreodaphne kavaiensis H. Mann.
Wickstrœmia elongata Gray.
  fœtida Gray.
  sandwicensis Meisn.
  Uva-ursi Gray.
  buxifolia Gray.
  phillyræfolia Gray.
Chenopodium sandwichieum Moq.
Ptilotus sandwicensis Gray.
Charpentiera ovata Gaud.
Urtica sandwicensis Wedd.
Urera glabra Wedd.
  sandwicensis Wedd.
Bœhmeria stipularis Wedd.
Pipturus albidus Gray.
Neraudia melastomæfolia Gaud.
  sericea Gaud.
Touchardia latifolia.
Euphorbia clusiæfolia Hook. & Arn.
  Remyi Gray.
  multiformis Gaud.
  Hookeri Steud.
  cordata Meyen.
Antidesma platyphyllum H. Mann.
Phyllanthus distichus Hook. & Arn.
Claoxylon sandwicensis Müll.
Peperomia pallida A. Dietr.
  membranacea Hook. & Arn.
  Gaudichaudii Miq.
  sandwicensis Miq.
  insularum Miq.
  latifolia Miq.
  hypoleuca Miq.
  Macræana Miq.
  leptostachya Hook. & Arn.
  ———— n. sp.
Pritchardia Martii Gaud.
  Gaudichaudii Herm. Wendl.
  ———— n. sp.
Freycinetia arborea Gaud.
Sisyrinchium acre H. Mann.
Smilax sandwicensis Kunth.
  anceps Willd.
  ———— sp. alt.
Anœctochilus sandwicensis Lindl.
  Jaubertii Gaud.
Liparis hawaiiensis H. Mann.
Dracæna aurea H. Mann.
Astelia Menziesiana Smith.
  veratroides Gaud.
Joinvillea ascendens Gaud.
Cyperus trachysanthos Hook. & Arn.

Cyperus Prescottianus Hook. & Arn.
caricifolius Hook. & Arn.
multiceps Hook. & Arn.
Kunthianus Gaud.
phleoides Nees.
hawaiiensis H. Mann.
Rhynchospora lavarum Gaud.
thyrsoidea Nees. & Meyen.
Cladium leptostachyum Nees. & Meyen.
Baumea Meyenii Kunth.
Vincentia angustifolia Gaud.
Gahnia Gaudichaudii Steud.
Beechyi H. Mann.
globosa H. Mann.
Oreobolus furcatus H. Mann.
Scleria testacea Nees.
Carex Commersoniana Gilb.
Meyenii Nees.
oahuensis C. A. Meyer.
nuptialis Boott.
Prescottiana Boott.
Uncinia Lindleyana Kunth.
Panicum nephelophilum Gaud.[1]
montana Gaud.
pellitum.
tenuifolium, Hook. & Arn.
Beecheyi.
isachnoides Munro.
Poa oahuensis Kunth.
monticola Kunth.
variabilis Kunth.
——— sp.
——— sp. alt.
Isachne distichophylla Munro.
Cenchrus agrimonioides Munro.
Garnottia patula Munro.
Agrostis sandwicensis Munro.
Calamagrostis, sp.
Trisetum glomeratum Munro.
Eragrostis nana Munro.
Festuca, sp.
Schizostachyum decompositum Munro.
Koeleria glomerata Kunth.

Plants not peculiar to the Hawaiian Islands, and not introduced by Whites.

— Cardamine hirsuta Linn.
— Senebiera didyma Pers.
— Capparis sandwicensis D C.
— Sesuvium portulacastrum Linn.
† Calophyllum inophyllum Linn.
— Gossypium religiosum Linn.
— Hibiscus tiliaceus Linn.
Thespesia populnea Corr.
— Sida fallax Walp.
rhombifolia Linn.
Malvastrum tricuspidatum Gray.
— Waltheria americana Linn.
— Tribulus cistoides Linn.
Colubrina asiatica Brongn.
Alphitonia excelsa Riessek.
Dodonæa viscosa Linn.
— † Cardiospermum Halicacabum Linn.
Rhus semialatum Murr.
† Crotalaria sericea Retz.
— † Tephrosia piscatoria Pers.
† Sesbania grandiflora Poir.
— * Desmodium triflorum D C.
Strongylodon lucidum Seem.
Dioclea violacea Mart.
Mucuna gigantea D C.
urens D C.
* Phaseolus truxillensis H B K.
* semierectus Linn.
Vigna lutea Gray.
† Dolichos lablab Linn.
† Cajanus indicus Spreng.
Cæsalpinia (Guilandina) Bonduc Benth.
Osteomeles anthyllidifolia Lindl.
Drosera longifolia Linn.
Metrosideros polymorpha Gaud.
† Psidium Guajava Linn.
Eugenia (Jambosa) malaccensis Linn.
Lythrum maritimum H B K.
Cuphea balsamona Cham. & Schlecht.
— † Jussiæa villosa Linn.
Lagenaria vulgaris Ser.
Curcubita maxima Duch.
† Papaya vulgaris D C.
Hydrocotyle interrupta Muhl.
Viscum moniliforme Blume.
Nertera depressa Banks.
† Richardsonia scabra St. Hil.
Pæderia fœtida Linn.
Canthium lucidum Hook. & Arn.
— † Morinda citrifolia Linn.
Adenostemma viscosum Forst.
— * Ageratum conyzoides Linn.
Gnaphalium albo-luteum Linn.
* Sonchus asper Linn.
— Scævola sericea Forst.
Cyathodes Kamehamehæ Cham.

[1] The grasses are still in the hands of General Munro, and therefore only this very imperfect list can be given. W. T. B.

Cyathodes imbricata Stschelglew.
Lysimachia lineariloba Hook. & Arn.
— Plumbago zeylanica Linn.
Solanum oleraceum Dunal.
— aculeatissimum Jacq.
— nigrum Linn.
Physalis peruviana Linn.
Herpestis Monniera H B K.
— Plectranthus parviflorus Willd.
— * Priva aspera H B K.
— Vitex trifolia Linn.
— † Cordia subcordata Lam.
— Heliotropium anomalum Hook. & Arn.
— Curassavicum Linn.
Batatas acetosæfolia Choisy.
† edulis Choisy.
pentaphylla Choisy.
Ipomœa Bona-nox Linn.
insularis Steud.
— pes-capræ Sweet.
Turpethum R. Br.
Forsteri Gray.
palmata Forsk.
Cressa cretica Linn.
— Vinca rosea Linn.
Pisonia grandis Parkinson.
excelsa Blume.
— Bœrhaavia diffusa Linn.
Rumex longifolius? Gray.
— * Polygonum glabrum Willd.
Cassytha filiformis Linn.
— Chenopodium murale Linn.
— album Moq.
— ambrosioides Linn.
— Batis maritima Linn.
† Basella rubra Linn.
Achyranthes splendens Mart.
— bidentata Blume.
velutina Hook. & Arn.
Aerva sericea Moq.
— Euxolus viridis Linn.[1]
— lineatus Moq.
— Fleurya interrupta Gaud.
Pilea peploides Hook. & Arn.
— Artocarpus incisa Linn.
— Brousonettia papyrifera Vent.
Morus pendulina Endlich.
† indica Rumph.

Euphorbia atoto Forst.
— * pilulifera Linn.
* Heliscopia Linn.
* Phyllanthus Niruri Linn.
Aleurites moluccana Willd.
Manihot utilissima Pohl.
† Ricinus communis Linn.
† Piper methysticum Forst.
Cocos nucifera Linn.
— Pandanus verus Rumph.
Colocasia esculenta Schott.
Alocasia macrorhiza Schott.
Tacca pinnatifida Forst.
— Naias major All.
— Ruppia maritima Linn.
— Potomogeton Gaudichaudii Cham.
— hawaiiensis Cham.
— pauciflorus Pursh.
Musa —— sp.
† —— sp. alt.
— Zingiber Zerumbet Ross.
* Canna indica Linn.
† Helmia bulbifera Kunth.
† Dioscorea pentaphylla Linn.
Commelyna cayennensis Rich.
* Tradescantia floribunda Kunth.
Cordyline terminalis Kunth.
Dianella odorata Blume.
Luzula campestris D C.
— Cyperus mucronatus Rottb.
brunneus Sw.
polystachus Rottb.
pennatus Lam.
viscosus Ait.
cæspitosus Poir.
paniculatus Hook. & Arn.
strigosus Linn.
auriculatus Nees. & Meyen.
* Kyllingia monocephala Rottb.
Elœocharis obtusa Schult.
palustris R. Br.
— Scirpus maritimus Linn.
— riparius Presl.
Fimbristylis cymosa R. Br.
— umbello-capitata Steud.?
Gahnia globosa H. Mann.
Carex festiva Dewey.

Species marked with a dagger (†) are perhaps of aboriginal introduction; those marked with an asterisk (*) possibly of recent introduction; those marked with a dash (—) are *par excellence* lowland and maritime.

[1] This should rather be placed among the plants accidentally introduced in recent time. W. T. B.

For convenience, the Flora of the Hawaiian Islands may be divided into five regions: the dry alluvial plains on the shore or *Maritime Region*, the *Lowland Region*, *Higher Wooded Region*, *Wet Mountain Region* and *Dry Mountain Region*.[1]

I. Maritime Region. Besides the plants in the previous list, the following are characteristic of this zone.

Cleome sandwicensis.
Hibiscus Youngianus.
Erythrina monosperma.
Lipochæta succulenta.
Lycium sandwicense.
Nama sandwicensis.
Erythræa sabæoides.
Pritchardia sp.

II. Lowland Region. This extends to about 1,000 feet above the sea, and is principally characterized by *Aleurites moluccana*, *Jambosa malaccensis*, *Hibiscus tiliaceus*, *Pandanus odoratissimus*, and *Cordia subcordata*.

Capparis sandwicensis.
Abutilon incanum.
Sida fallax.
Hibiscus Youngianus.
    tiliaceus.
Gossypium (three species).
Tribulus cistoides.
Waltheria americana.
Oxalis corniculata.
    Martiana.
Cardiospermum Halicacabum.
Eugenia malaccensis.
Lythrum maritimum.
Jussiæa villosa.
Sicyos cucumerinus.
Morinda citrifolia.
Adenostemma viscosum.
Vittadinia arenaria.
    conyzoides.
Erigeron canadense.
Scævola sericea.
Plumbago zeylanica.
Physalis peruviana.
Plectranthus parviflorus.
Myoporum sandwicense.
Cordia subcordata.
Ipomœa Bona-nox.
    insularis.
    palmata.
Cuscuta sandwichiana.
Bœrhaavia diffusa.
Santalum ellipticum (var.)
Chenopodium (three species).
Euxolus lineatus.
Euphorbia multiformis.
Aleurites moluccana.
Ricinus communis.
Tacca pinnatifida.
Zinziber Zerumbet.
Cordyline terminalis.

III. Higher Wooded Region. This is the forest region. The following species are found here; those marked * in the higher part. Only those marked — are not endemic.

* Ranunculus hawaiiensis.
*   mauiensis.
Nephroica Ferrandianus.
Lepidium serra.
— Cardamine hirsuta.
Viola Chamissoniana.
Isodendrion (all of the species).
Xylosma hawaiiense.
Pittosporum (all of the species).
Silene lanceolata.
Schiedea (most of the species).
— Alsinidendron trinerve.
Calophyllum inophyllum.
Eurya sandwicensis.
Hibiscus Brackenridgii.
    Arnottianus.
Sida Meyeniana.
Elæocarpus bifidus.
* Geranium arboreum.
Pelea (all of the species).
Melicope (all of the species).
Platydesma campanulata.

[1] Jules Remy distinguishes five zones thus: Littoral. Tropical (from the base of the hills to the forests), Forest, Mountainous or Sub-Alpine, and Alpine. The absence of anything like an Alpine region will be evident on inspection of the above lists. W. T. B.

Zanthoxylon (all of the species).
Byronia sandwicensis.
Perrottetia sandwicensis.
Colubrina oppositifolia.
— Alphitonia excelsa.
— Dodonæa viscosa.
— Rhus semialatum.
Vicia Menziesii.
— Strongylodon lucidum.
— Mucuna (both species).
— Dioclea violacea.
— Canavalia galeata.
Vigna oahuensis.
sandwicensis.
— Cæsalpinia Bonduc.
kavaiensis.
Acacia koa.
Cassia Gaudichaudii.
* Rubus (both species).
Osteomeles anthyllidifolia.
Broussaisia arguta.
Metrosideros (all of the species).
Psidium Guajava.
Eugenia sandwicensis.
Sicyos (all of the species).
Hillebrandia sandwicensis.
Sanicula sandwicensis.
Hedera Gaudichaudii.
Heptapleurum kavaiense.
Dipanax Mannii.
Reynoldsia sandwicensis.
Tetraplasandra hawaiiensis.
Triplasandra oahuensis.
Viscum moniliforme.
Coprosma (all of the species except *pubens*)
Canthium lucidum.
Psychotria (both species).
Straussia (all of the species).
Bobea (both species).
Guettardella sandwicensis.
Gardenia Brighami.
Remyi.
Gouldia sandwicensis.
Kadua (all of the species).
Adenostomma viscosum.
Coreopsis macrocarpa.
Macræi.
cosmoides.
Bidens sandwicensis.
hawaiiensis.
Lipochæta australis.
Dubautia (all of the species).
Raillardia latifolia.
scabra.
laxiflora.
Raillardia Hillebrandii.
Hespcromannia arborescens.
Rollandia (all of the species).
Delissea (seventeen species).
Cyanea (six species).
Clermontea (both species).
Brighamia insignis.
Scævola Gaudichaudii.
Chamissoniana.
mollis.
glabra.
Vaccinium penduliflorum.
Cyathodes (both species).
Maba sandwicensis.
Sapota sandwicensis.
Myrsine (all of the species).
Lysimachia (both species).
Plantago princeps.
pachyphylla.
Cyrtandra (all of the species).
Solanum sandwicense.
incompletum.
Nothocestrum (all of the species).
Phyllostegia (most of the species).
* Sphacele hastata.
Stenogyne (most of the species).
Myoporum sandwicense.
Ipomœa tuberculata.
Bona-nox.
Bonamia Menziesii.
Cuscuta sandwichiana.
Alyxia olivæformis.
Rauwolfia sandwicensis.
Ochrosia sandwicensis.
Olea sandwicensis.
— Pisonia (both species).
— Phytolacca bogotensis.
Rumex giganteus.
Santalum (two species).
Exocarpus Gaudichaudii.
Oreodaphne kavaiensis.
Wickstrœmia (three species).
Ptilotus sandwicensis.
Fleurya interrupta.
Urera (both species).
Pilea peploides.
Bœhmeria stipularis.
Neraudia melastomæfolia.
Touchardia latifolia.
Morus pendulina.
Euphorbia clusiæfolia.
Remyi.
Hookeri.
Antidesma platyphyllum.
Phyllanthus distichus.

Claoxylon sandwicensis.
Peperomia (most of the species).
Pritchardia (two species).
Freycinetia arborea.
Smilax (three species).
Commelyna cayennensis.
* Anœchtochilus (two species).
Liparis hawaiiensis.
Dracæna aurea.
— Cordyline terminalis.
Dianella odorata.
Astelia (two species).
Joinvillea ascendens.
Gahnia Beecheyi.
globosa.
Uncinia Lindleyana.

IV. Mountain Region. Wet and wooded between the lower and higher cloud level, 3,500–6,000 feet.

Metrosideros polymorpha (dwarf).
Gunnera petaloidea.
Coprosma pubens.
Labordea fagræoides.
Vittadinia (several species).
Hedera platyphylla.
Astelia Meyeniana.

V. Upper Mountain Region. A small region on the summits of West Máui and Kauaì, which lies above 6,000 feet, and which is not wooded.

Viola kavaiensis.
mauiensis.
Geranium cuneatum, var. hololeucum.
Drosera longifolia.
Acaena exigua.
Lagenophora mauiensis.
Argyroxiphium (two species).
Wilkesia gymnoxiphium.
Raillardia montana.
Lobelia Gaudichaudii.
Vaccinum reticulatum.
Oreobolus furcatus.
and some Gramineæ.

EXPLANATION OF THE PLATES.

XXI. Alsinidendron trinerve.

a. Stamen. *b.* Pistil. *c.* Capsule.

XXII. Platydesma campanulata.

a. Section of bud. *b.* Section of fruit. *c.* Stamen. *d.* Pistil.

XXIII. Brighamia insignis.

a. Plant much reduced.
b. Head " "
c. Leaf of natural size.
d. Flowers " "
e. Fruit " "
f. Cross-section of bud.
g. " " " fruit.
h. Section of flower.

Published, March, 1869.

XVI. *The Geographical Distribution of the Native Birds of the Department of Vera Cruz, with a List of the Migratory Species.* By F. Sumichrast. Communicated to the Smithsonian Institution, and published by permission of the Secretary. Translated from the French, by T. M. Brewer, M. D.

Read December 16, 1868.

I HAVE cited in this list only those species in regard to the determination of which I have no doubt, and which I have myself been able, with but few exceptions, to observe in the places of their abode. In a country in which the altitude of very few points has been ascertained with exactness, I have met with great difficulties in determining the limits in height to which each species attains. I have used for my present work the measurements of the French Scientific Commission taken on their route from Vera Cruz to Mexico. It is true I have never had before my own eyes the original observations of these gentlemen, and this must be my excuse for any errors which I may have made.

I have endeavored, as will be seen, to trace the distribution of the birds of the State of Vera Cruz, which are the best known to me, in such a manner as to suggest certain general facts that may serve as the basis of more extended researches. I do not doubt that when the catalogue of the native birds shall have been more completely prepared than at present, and when the observations upon their mode of distribution shall have been multiplied, that we shall be able to recognize, as in conformity with actual facts, the division into three regions which appears to me to characterize the State of Vera Cruz in a zoölogical point of view.

The three regions here referred to and generally recognized, are the hot, the temperate, and the alpine. All these are met with in ascending from the sea-level at Vera Cruz to the snow-capped summit of Orizaba.

In this undertaking I have been aided by Prof. S. F. Baird in numerous communications. But for his assistance the preparation of these notes would have been almost impossible.

F. Sumichrast.

Orizaba, *July 20th*, 1868.

Turdidæ.

1. *Catharus melpomene* Cab. Vulg. *Chepito.* Temperate and alpine regions.
2. *Catharus occidentalis* Scl. Vulg. *Chepito.* Alpine region.

These two species of *Catharus* have, with only slight variations, the same geographical distribution. Both inhabit the most elevated portions of the temperate region and the lower zone of the alpine. The *C. occidentalis* ascends to an altitude of 2500 metres[1] among the mountains of Orizaba, while the *C. melpomene* comes down as low as Orizaba in the temperate region, that is, to a height of 1200 metres, and even nests in the gardens of that city.

3. *Catharus mexicanus* Bp. Temperate region. Having been able in the course of several years to procure but a single individual of this species, I have reason to regard it as quite rare, and perhaps as confined to the temperate region.

4. *Turdus Audubonii* Baird. Vulg. *Solitario.* Alpine region. This species is common in the pine woods of the alpine region in the district of Orizaba. I have obtained it at all seasons in Moyoapam, a locality the height of which approximates 2500 metres. It is, however, also found near Orizaba.

[1] For all practical purposes the metre may be estimated at about 3¼ feet. — T. M. B.

5. *Turdus assimilis* Cab. Vulg. *Mislo. Primavera de collar.* Temperate and hot region. Judging from the large number of localities in which this species is found in the State of Vera Cruz, it must have a very extended area of distribution, — restricted, however, in the hot and temperate regions to an altitude of 1300 metres, — for I have procured specimens on the Gulf coast, in the forests of Muero, at Potrero, near Cordova (590 metres), at Orizaba (1220 metres), etc. Although a sedentary bird, it is not always to be found in the same localities, but changes its residence frequently, influenced by the ripening of the berries upon which it feeds.

6. *Turdus Grayi* Bp. Vulg. *Primavera.* Hot and temperate regions. Perhaps the most abundant of all the Mexican *Turdidæ,* and resident in the hot and temperate regions. I do not believe that it reaches the height of 1300 metres.

7. *Turdus migratorius.* Vulg. *Primavera real.* Alpine region. I place this species among the resident birds of this department from the fact of my having, in the month of July, 1868, found its young in large numbers among the mountains of Orizaba at an altitude of about 2400 metres. It is one of the most abundant of the thrushes in the alpine region, especially frequenting the clearings and the natural openings in the midst of the forests of pine, which it animates by its lively manners and the sweetness of its notes. A single instance is mentioned of its occurrence, during the past ten years, near the city of Orizaba.

8. *Turdus infuscatus* Lafr. Vulg. *Primavera del Monte.* Temperate and alpine regions. The lower portions of the arctic region and the upper and wooded part of the temperate are the favorite resort of this thrush. It is quite common in these localities at the foot of the mountains, at an elevation varying from 1250 to 2500 metres.

9. *Turdus pinicola.* Alpine region. I have in a single instance found this rare thrush at Moÿoapam, in the mountains, north of the valley of Orizaba, at the height of some 2500 metres, in the pine woods.

10. *Harporhynchus longirostris.* Temperate region. Quite common in the Orizaba district, at the height of from 1000 to 2000 metres.

11. *Mimus polyglottus.* Vulg. *Cenzontle.* Hot and temperate regions. The Mocking-bird is one of the few species that are found equally abundant in localities the most widely different both as to height and climate. It is, in fact, to be found from the Gulf shores as far up as the great plains of the plateau, but always only in the more open portions. It nests in the neighborhood of Orizaba.

12. *Melanotis cærulescens.* Vulg. *Mulato.* Temperate region. Common in the temperate region, but passing beyond its bounds in each direction, being found in certain localities in the hot region and in the alpine region to an altitude of at least 1300 metres.

Harporhynchus curvirostris I have never met with except on the plateau of Mexico, and though it may be found at a few elevated points of the department of Vera Cruz, I am yet of the belief that the localities (Mirador, Cordova, and Orizaba) cited in the "Review of North American Birds," page 45, may be incorrect. At any rate, they only indicate its true centre of habitation to be the central plateau where it nests.

To the preceding species, which I regard as resident in this department, I will here add the following which occur only as transient visitors:

Turdus mustelinus.

Turdus fuscescens. A small *Hylocichla,* of which I never met with but a single specimen, several years since in the hot region, seems to me to have presented all the characteristics of the *T. fuscescens*, as given in Prof. Baird's "Birds of North America," and I mention it here in passing.

Galeoscoptes carolinensis.

Cinclidæ.

13. *Cinclus mexicanus* Sw. Vulg. *Tordo de agua.* Alpine region. A species essentially alpine, but which follows in its coming the watercourses that descend from the Cordilleras down even to the temperate region. We may fix the limits of its distribution at a height varying from 1000 to 2500 metres.

Saxicolidæ.

14. *Sialia azurea* Sw. Vulg. *Golondrina azul.* Temperate region. Although this species is unquestionably a resident of the department, it is hardly to be found, except at intervals, in the same localities; at these periods of appearance it is very common throughout the entire temperate region, and from there ascends to localities having a height of at least 2000 metres.

15. *Sialia mexicana.* Alpine region. This species appears to belong exclusively to the alpine region on the Popocatepetl. I have found it in great numbers at the extreme limits of vegetation. The localities (Cordova, Jalapa) indicated as the places of occurrence of this *Sialia* by Mr. Sclater, are probably due to imperfect information of the collector. It has never been seen, so far as I know, near Orizaba, the climate and productions of which are analogous to those of these two cities.

Paridæ and Certhiadæ.

All the species of this family that to my knowledge inhabit the department are confined to the alpine region, of which they form a characteristic feature. I shall therefore confine myself to a mere mention of the localities in which I have actually observed them.

16. *Lophophanes Wollweberi.* Vulg. *Mascarita.* Alpine region. Mountains of San Diego, valley of Orizaba; at the height of about 1850 metres.

17. *Parus meridionalis.* Vulg. *Mascarita.* Alpine region. Moyoapam, near Orizaba; height of about 2500 metres.

18. *Psaltriparus melanotis.* Alpine region. Mountains of San Diego; height about 1850 metres.

19. *Sitta carolinensis* (vel *aculeata*). Alpine region. Prof. Baird (in litt.) refers to *S. carolinensis*, a *Sitta* killed at Moyoapam, 2500 metres, a specimen of which I had sent to him. I have also obtained it at a great height upon Popocatepetl.

20. *Sitta pygmæa.* Alpine region. This little species ascends to the very extreme limits of vegetation on the peak of Orizaba and Popocatepetl.

21. *Certhia mexicana.* Alpine region. Moyoapam, Popocatepetl; peak of Orizaba.

Troglodytidæ.

22. *Campylorhynchus pallescens.* Vulg. *Matraca.* Alpine region. This is the only species of this genus that is peculiar to the alpine region in this department. The specimens of *C. megalopterus* — identical, as it appears, with *C. pallescens* — indicated by Mr. Sclater as occurring at Jalapa, must have been, beyond doubt, collected in the neighboring mountains. Near Orizaba I have only found the *C. pallescens* between an elevation of from 1500 to 2000 metres.

23. *Campylorhynchus zonatus.* Vulg. *Matraca.* Temperate region. Although more especially belonging to the temperate region, this species is also found in the hot lands of the eastern part of the department. It nests near Orizaba. The plumage of the young birds is so different from that of the adults that it is not impossible that one of the species described by authors as the black-capped may have been based upon young birds of the *C. zonatus.* The limit of their extension, as to height. does not exceed 1300 metres.

In the "Review of North American Birds," p. 107, Prof. Baird has fallen into an error from the want of exact information in regard to the habitat of the *C. humilis,* and cites specimen No. 29,225 of the Smithsonian Museum as having come from Orizaba. This indication is incorrect. The specimen in question came from Guchitan (Isthmus of Tehuantepec), where I obtained it in March, 1862. I sent it from Orizaba to Prof. Baird without indicating its habitat. It is not therefore surprising that this neglect on my part has led to a mistake, which I here take occasion to repair.

24. *Catherpes mexicanus.* Vulg. *Saltapared.* Temperate region, plateau. Very common on the plateau of Mexico, where it probably has its principal centre of propagation. This bird is also found in the temperate region of the department of Vera Cruz. In Orizaba it nests in the houses. Its nest, very skillfully wrought with spiders' webs, is built in the crevices of old walls, or in the interstices between the tiles under the roofs of the houses.

25. *Heterorhina prostheleuca.* Hot, temperate, and alpine regions. This pretty bird, very generally distributed throughout the hot and temperate regions of the department, also extends into the alpine region to the height of at least 2000 metres, as I have had evidenced by specimens which I have obtained at Moyoapam, in the mountains northwest of the valley of Orizaba. Its nest, which I have found in the same locality, is formed of mosses interwoven with great skill. The interior of those which I have examined were all lined with red feathers from the abdomen of the *Trogon mexicanus.* It is suspended or rather fastened to the branches of shrubs, and so skillfully done by its cunning owner as to be readily mistaken for a bunch of moss.

26. *Pheugopedius maculipectus.* Hot and temperate region. Belonging to the fauna of the hot and temperate regions it does not extend beyond the height of about 1200 metres, or about the altitude of Orizaba, where it becomes a somewhat rare species.

27. *Troglodytes brunneicollis.* Vulg. *Sonajita.* Alpine region. One of the most common birds of the alpine region, between the height of 1500 and 2500 metres, and confined to this region.

I have obtained near Orizaba two other species of *Troglodytes,* the *T. aztecus* Baird, and the *Cistothorus stellaris,* but I am but imperfectly acquainted with their geographical distribution, and therefore only mention them in passing.

Sylvicolidæ.

Of the four sub-families, *Sylvicolinæ, Geothlypinæ, Icterianæ,* and *Setophaginæ,* into which Mr. Baird divides the group of *Sylvicolidæ* ("Review of North American Birds"), the first three are represented in the department of Vera Cruz almost only by migratory species, which merely come here to pass the winter, or pass through on their way to more southern regions. I will indicate in their order the resident species, adding to the name of each the localities in which I have observed them. The resident species are: —

28. *Parula superciliosa.* Alpine region. I have only found this pretty species in the alpine

region, that is to say near Orizaba, at about 1800 metres, and at Moyoapam, 2500 metres, in the forests of pines and oaks.

29. *Dendroica olivacea.* Alpine region. One of the most characteristic species of the alpine region. It is there common among the forests, from a height of 1500 to that of 3000 metres.

30. *Geothlypis speciosa.* Alpine region. To this species I refer a *Geothlypis*, occurring in the alpine region among the mountains of Orizaba, and which belongs to the collection of my friend M. Mateo Botteri.

31. *Geothlypis poliocephala.* Hot region? Of this species I have procured but a single specimen, obtained near the upper limits of the hot region, at the height of about 450 metres. I do not know whether it is peculiar to this region.

32. *Granatellus Sallaei.* Hot region. Found in hot and hot-temperate localities. I have found it at Portrero, near Cordova, a height of 590 metres.

33. *Basileuterus culicivorus.* Temperate region.

34. *Basileuterus rufifrons.* Temperate region.

35. *Basileuterus belli.* Temperate region.

These three species have their maximum of development in the temperate region, but they pass beyond its limits both into the hot region and into the alpine. I have seen them within the lower portions of the latter region at a height of about 2000 metres. These birds frequent thickets, ravines, and dark woods.

36. *Setophaga picta.* Alpine region. I have only observed this species in the alpine region, between a height of 1400 and 2500 metres.

37. *Setophaga miniata.* Vulg. *Guajololito.* Temperate and alpine regions. Common at all heights between 500 and 2500 metres.

38. *Euthlypis lachrymosa.* Temperate region. This quite rare bird seems to be fixed by its own choice in temperately warm localities, that is to say, at an elevation between 500 and 1000 metres. Its habits are decidedly different from those of the other *Setophaginæ.* It walks rather than perches, and when running or hopping on the ground, might be taken for one of the *Formicariidæ.* From time to time it raises itself while pirouetting to a small height, spreading its tail and uttering a low cry of pleasure. I have killed one of these birds in the midst of an innumerable column of tepegua ants, *Eciton mexicanum,* upon which, without doubt, it was feeding. I have procured several in the woods, covering the calcareous rocks of Penuela, near Cordova, at about 700 metres.

39. *Cardellina rubra.* Vulg. *Cardelin.* Alpine region. This species is one of the most characteristic of the alpine region. It is frequently met with there among the pine woods which it enlivens by the brilliancy of its plumage and the graceful vivacity of its movements. Common among the mountains of Orizaba, it there attains to an elevation of from 2000 to 3000 metres.

Migratory Species.

Mniotilta varia. Everywhere in winter.

Parula americana. Orizaba.

Helminthophaga celata. Orizaba.

Helminthophaga ruficapilla. Orizaba.

Helmitherus vermivorus. Mountains of Orizaba.

Dendroica virens. Everywhere.

Dendroica occidentalis. Moyoapam. 2500 metres.

Dendroica nigrescens. Orizaba; rare.

Dendroica coronata. Everywhere.

Dendroica Audubonii. Tecamaluca, near Orizaba. 1400 metres.

Dendroica Blackburniæ. Orizaba. Very rare.

Dendroica æstiva. Rare at Orizaba; common on the plateau.

Dendroica dominica. Orizaba, where it arrives about the 10th of August.

Seiurus aurocapillus. Orizaba and other places.

Seiurus noveboracensis. Orizaba and other places.

Geothlypis trichas. Orizaba.

Icteria virens. Vulg. *Arriero.*

The data which I possess in regard to this species do not enable me to say with certainty whether the individuals I have seen are really referable to the *I. virens,* and are therefore migratory, or whether they should be regarded as belonging to the species described by Bonaparte and Lichtenstein under the names of *I. Velasquezi* and *auricollis.*

Myodioctes mitratus. Orizaba.

Myodioctes pusillus. Everywhere.

Setophaga ruticilla. Observed everywhere in the hot region.

Hirundinidæ.

40. *Progne subis.* Alpine region. Resident in the alpine region to which it seems to confine itself.

41. *Progne leucogaster.* Hot and temperate region. This species which we find on the shores of both oceans, does not extend into the department of Vera Cruz farther than to the height of 1200 metres. It nests at Orizaba in the steeples of churches and old buildings.

42. *Petrochelidon Swainsonii.* Region of the plateau. This species, peculiar to the plateau, is rarely found within the department.

43. *Hirundo horreorum.* Region of the plateau. The same is also true of this species.

44. *Tachycincta thalassina.* Hot and temperate region. The plateau. We find this swallow at almost all heights, and almost everywhere very abundant.

45. *Tachycincta bicolor.* The plateau of Mexico is probably the favorite residence of this swallow, which very rarely extends into Vera Cruz.

46. *Stelgidopteryx fulvipennis.* This species is sufficiently distinct from the preceding (45). I also think that the *S. serripennis* is found in the department, coming in winter.

The powers of locomotion and the migratory instincts which the *Hirundinidæ* possess to so high a degree, render it difficult to fix with exactness their geographical distribution respectively. Among those which I have mentioned the two species of *Progne* are the only ones whose limits appear to me to be clearly fixed.

Vireonidæ.

47. *Neochloe brevipennis.* Temperate region. This exceedingly rare bird has only been found, so far as I am aware, at Orizaba, by M. Botteri. In the course of many years he was able to procure but a very few specimens.

48. *Vireosylvia flavoviridis.* Temperate region. Alpine region? I have found this bird at the height of 1400 metres among the mountains in the neighborhood of Orizaba.

49. *Cyclorhis flaviventris.* Vulg. *Pajaro perrico.* Temperate region. Common everywhere throughout the temperate region to a height not exceeding 1300 metres.

50. *Vireolanius melitophrys.* Temperate region. All the specimens, and they have not been many, which I have seen of this bird, have been found in the upper extremity of the temperate region, at the height of about 1500 metres. It is probable that to very nearly the same zone belongs the *Vireolanius pulchellus*, which I have myself never met with, but which was found near Mirador by M. Sartorius.

The two species which follow, and which are found in winter in the department, are, without doubt, to be considered as only migratory.

Vireosylvia solitaria.

Vireosylvia gilva.

51. *Vireosylvia Huttoni.* Alpine region. Resident.

AMPELIDÆ.

52. *Ptilogonys cinereus.* Vulg. *Burrion jilguero.* Alpine region. This bird attaches itself by preference to the alpine region, although it is to be found at the foot of the mountains in the valley of Orizaba (1250 metres). In the alpine region it ascends to the height of nearly 3000 metres.

53. *Myiadestes obscurus.* Vulg. *Jilguero ordinario.* Alpine region. The breeding places of this species appear to me to be chiefly in the alpine region, to the height of at least 2500 metres. It is, however, found as low down as 1000 metres, and possibly still lower.

54. *Myiadestes unicolor.* Vulg. *Jilguero fino, Clarin.* Temperate region. As a singing bird this *Myiadestes* is one of the most characteristic species of the temperate region. It is especially the deep ravines of the cantons of Jalapa, Songolica, etc., that these birds frequent.

55. *Phœnopepla nitens.* Vulg. *Reyecito.* Plateau. Well distributed throughout the plateau of Mexico, this species only ranges, in the valley of Orizaba, to the height of about 1500 metres, and, as I believe, comes even thus far but rarely. It is, on the other hand, very common at Tehuantepec (State of Puebla, near Mexico), etc.

The only migratory species of this family which is found everywhere, and in great abundance in winter, is *Ampelis cedrorum*, known as the *Chinito*, and very highly appreciated by the Mexican epicures.

LANIIDÆ.

56. *Collurio excubitoroides.* Vulg. *Verdugo.* Plateau and temperate region. This species is probably resident in the plateau of Mexico, where it is common. In the department of Vera Cruz it is seldom found below 800 or 1000 metres. I do not remember to have ever met with a single specimen in the hot region.

CŒREBIDÆ.

57. *Cœreba carneipes.* Hot region. A bird of the hot lands, but wanders to the height of 1200 metres, as it reaches even Orizaba.

58. *Diglossa baritula.* Vulg. *Picochueco, Mielero.* Alpine region. I consider the alpine region as the real centre of propagation of this bird. I have there found it at the height even of 3000 metres. It is not very rare in the more elevated parts of the canton of Orizaba. Its general habits, and its manner of feeding, are analogous to those of the *Trochilidæ*. It is known by the common names of *Mielero* or Honey-eater, and *Pico chueco* or distorted beak.

TANAGRIDÆ.

59. *Pitylus poliogaster.* Vulg. *Pepitero.* Hot region. A species peculiar to the hot region, but which ascends even to the height of 1000 metres at the time of the ripening of certain kinds of berries.

60. *Saltator magnoides.* Hot region. Also confined to the hot region, the limits of which it rarely passes farther than to the height of 900 metres.

61. *Saltator atriceps.* Hot and temperate regions. Found in the same latitude with the preceding, but extending its movements to the height of at least 1200 metres. It is found near Orizaba, where *S. magnoides* never appears.

62. *Saltator grandis.* Vulg. *Terbero.* Hot and temperate regions. This third species of Saltator is very nearly equally abundant in both the hot and the temperate regions, and even passes beyond the limits of the latter. In fact, in the valley of Orizaba, it ascends to the height of 1500 metres.

63. *Buarremon brunneinuchus.* Vulg. *Gargantilla. Barba-blanca.* Temperate and alpine region. This is a species which, without being strictly characteristic of the alpine region, for it is quite frequently met with in the temperate, and even within the upper portions of the hot — is still most attached to wooded and mountainous localities, between 500 and 2000 metres in height.

64. *Buarremon albinuchus.* Vulg. *Frailecito.* Temperate region. This bird is one of those that add a positive character to the temperate region, from the fact that it is one of the few species that seems to belong exclusively to it. Its zone of habitation may be fixed at between 600 and 1100 metres.

65. *Chlorospingus ophthalmicus.* Temperate and hot region. The same may nearly be said of this species, the extreme limits of whose vertical extension cannot be very different.

66. *Lanio aurantius.* Hot region. A species peculiar to the hot lands, from which it never advances to a greater height than 400 or 500 metres. I have found it at San Uvero, near San Andres Tuxtla, at Omealca, etc. The physiognomy of this bird, in a state of nature, is not without a relationship to certain Tyrannidæ. I consider it more insectivorous than most of the Tanagers.

67. *Phœnicothraupis rubicus.* Hot region.

68. *Phœnicothraupis rubicoides.* Hot region.

These two species are peculiar to the hot region, though both occasionally pass beyond its limits, to the height even of 1000 metres, where, however, they are rare.

69. *Pyranga hepatica.* Vulg. *Colmenero* (Bee-eater). Hot, temperate, and alpine regions. This is, probably, of all the Tanagers of Mexico, the one having by far the widest geographical range. It is, in fact, to be found everywhere distributed from the coast of the Gulf to an altitude of at least 3000 metres.

70. *Pyranga bidentata.* Temperate region.

71. *Pyranga erythromelæna.* Vulg. *Misto colorado.* Temperate region.

I consider these two species as more or less characteristic of the temperate region. from the fact that all the individuals that I have been able to procure have been found in localities between 600 and 1200 metres in height.

72. *Rhamphocelus sanguinolentus.* Vulg. *Tordo mazon.* Hot region. This handsome species

belongs to the fauna of the hot lands, but is also found occasionally at the height of 1200 metres. Its appearance at so great an elevation is, however, but for short periods.

73. *Tanagra diaconus.* Vulg. *Nevadito.* Hot region. This is yet another species belonging to the hot region that occasionally advances to the height of 1000 metres. This, however, is not surprising, nor is it a fact that in the least invalidates the geographical division here established. Certain species of birds, and most especially the berry-eating birds, are residents of a region during the period of reproduction, and while they rear their young. When the latter are in a condition to attend to their own wants, they leave for a short time their usual abode, and sometimes extend their movements far beyond its limits, in search of the berries upon which they feed. These remarks especially apply to the Tanagers.

74. *Tanagra abbas.* Vulg. *Cuadrillero.* Hot and temperate region. The above line explains with sufficient exactness the distribution of this species, which is found from the shores of the Gulf as far as Orizaba. The *Cuadrilleros,* as these birds are called, like most of the Tanagers, move about in small flocks, and change continually from canton to canton, in search of berries, the period of whose maturity is determined, for the most part, by the height of the localities in which they grow. It is also to this instinct, or rather to this necessity of changing temporarily their domicile, that we must attribute the presence in localities, having an altitude of more than 1200 metres, of

75. *Chlorophonia occipitalis.* Hot region. And of

76. *Euphonia affinis.* And

77. *Euphonia hirundinacea.* Vulg. *Higuerillero.* Hot region. All of which species have their true centre of propagation in the hot region.

78. *Euphonia elegantissima.* Vulg. *Monjita.* Hot, temperate, and alpine region. More vagrant even than the preceding species. This bird is found at all heights. I have killed it at the altitude of 2000 metres, among the mountains of Orizaba.

79. *Euphonia Gouldii.* Hot region. The only specimen I have seen of this pretty species came from the hot lands, and from an altitude of 500 metres. There are also found, during the winter, three other species of Tanagers, in the department of Vera Cruz, but these I believe are only migratory. They are:—

Pyranga rubra, Pyranga æstiva, Pyranga ludoviciana.

Fringillidæ.

80. *Hesperiphona Abeillii.* Vulg. *Pepitero.* Temperate region (?). I have found this species but once, in August (?), at Orizaba, and I do not therefore know with exactness the limits of its geographical distribution. It is probable that the alpine region of the State of Vera Cruz can claim as one of its birds, the *Hesperiphona vespertina.* I met with it in May, 1857, in the pine woods of Monte Alto, about twelve leagues from Mexico.

81. *Carpodacus hæmorrhous.* Vulg. *Burrion.* Plateau. This species, common throughout the plateau, is also found in the elevated portions of the State of Vera Cruz.

82. *Chrysomitris notatus.* Temperate region.

83. *Chrysomitris mexicanus.* Vulg. *Dominiquito.* Temperate region.

These two species, though distributed throughout the greater portion of this department, have their chief development in the temperate region. The last named nests in the neighborhood of Orizaba.

84. *Chrysomitris pinus.* Vulg. *Dominiquito montero.* Plateau and alpine region. This bird

is found in the alpine region to the height of 2000 metres, and does not, I think, descend below 1000 metres. It most especially frequents the plateau.

85. *Curvirostra americana.* Vulg. *Pico cruzado.* Alpine region. I have obtained but a single specimen of this species at Moyoapam, in the alpine region of Orizaba, at the height of about 2500 metres. I do not know whether the species is resident, or whether it only comes to us in the winter.

86. *Plectrophanes melanomus.* Plateau. The great plains of the plateau are the usual abode of this species; from them it comes down to the distant intervals as far as Orizaba, 1220 metres.

87. *Junco cinereus.* Vulg. *Echa-lumbre, Ixtentlimuyotzi.* Alpine region. One of the most characteristic species of the alpine region. It ascends to the height of 3500 metres. and does not descend below 2000. Its common name, *Echa-lumbre*, signifies lightning-bird, because it is the popular belief that its eyes are phosphorescent in the dark.

88. *Atlapetes pileatus.* Alpine region. Exclusively belonging to the alpine region, this bird is common within the forests of pines and oaks, within the same extreme limits with the preceding.

89. *Aimophila rufescens.* Vulg. *Lanjero.* Temperate region. Common in the temperate region, where it is most abundant between the height of 600 and 1500 metres. In the upper alpine regions, that is, at a height between 3000 and 4000 metres, it is replaced by another species, which I believe to be *Aimophila superciliosa* Sw. Its nest, which is found quite frequently near Orizaba, is usually placed at the foot of a bush, and contains two eggs, entirely white. It is in the nest of this bird that the *Molothrus æneus*, which, as is well known, imposes its offspring upon the cares of other birds, deposits its eggs, which are white, like those of this *Aimophila*, but are larger and less oval.

90. *Peucæa Cassinii.* Temperate region. Resident in the valley of Orizaba.

91. *Embernagra rufivirgata.* Temperate and hot regions. I have found this species in localities quite remote from each other, and belonging both to the hot and to the temperate regions. In the latter it is found to the height of at least 1200 metres.

92. *Guiraca melanocephala.* Vulg. *Guionchi Tigrillo.* Alpine region and plateau. Quite common on the plateau, this species is also found in the alpine region to the height of 2500 metres, and never comes down below 1200.

93. *Guiraca concreta.* Hot region. Peculiar to the hot region, the limits of which it rarely leaves. The hamlet of Peñuela, near Cordova — about 750 metres — is the most elevated point at which I have met with it in the department.

94. *Cyanospiza parellina.* Hot region. The geographical distribution of this species is analogous to the preceding, and its elevation does not exceed 800 metres.

95. *Cyanospiza versicolor.* Vulg. *Prusiano.* I have had but few opportunities of ascertaining the geographic distribution of this species, which is quite rare in the State of Vera Cruz, and is found near Orizaba.

96. *Spermophila corvina.* Temperate region? The few specimens of this rare species that I have seen have been found near Orizaba.

97. *Spermophila Moreletii.* Vulg. *Frailecito.* Hot and temperate regions and plateau. From all parts of the State of Vera Cruz, except perhaps the alpine region. It is also found on the plateau.

98. *Sycalis chrysops.* Temperate region? I refer this species to the temperate region

from having found near Orizaba the only specimens that have been brought to my knowledge.

99. *Volatinia jacarina.* Vulg. *Locito.* Hot and temperate regions. Throughout the hot and temperate sections as far up at least as 1300 metres.

100. *Phonipara pusilla.* Hot? and temperate regions. Common in the valley of Orizaba to the height of 1400 metres.

101. *Chamæospiza torquata.* Vulg. *Gargantilla.* Alpine region. This species is exclusively confined to the alpine region, and is very generally diffused throughout the pine woods of the mountains of Orizaba, of which it is resident. The limits of the zone, within which it is found, are from 1500 to 3000 metres. The plumage and habits of this bird present a remarkable analogy to those of the *Buarremon brunneinuchus.* Both are ground birds, rather than perchers, and frequently meet together in the same localities.

102. *Pipilo maculatus.* Vulg. *Ruia.* Plateau and alpine region.

103. *Pipilo fuscus.* Vulg. *Vieja.* Plateau and alpine region.

Both of these *Pipilos* are common on the plateau of Mexico, where they have their principal development. They are also found, though in smaller numbers, in the alpine region, from which they never come, the first below 1400 metres, the second below 1200. Both birds nest on the plateau.

Among the resident species I must also include two other species that are not exclusively Mexican.

104. *Peucæa ruficeps.* Temperate region, and

105. *Spizella socialis.* Temperate region, which breed here as in the United States?

The following are migratory species and pass the winter in the department: —

Passerculus alaudinus.	Guiraca cærulea.
Melospiza Lincolnii.	Guiraca ludoviciana.
Coturniculus passerinus.	Cyanospiza ciris.
Euspiza americana.	Cyanospiza cyanea.
Cardinalis virginianus.	Chondestes grammaca.

Icteridæ.

106. *Molothrus æneus.* Vulg. *Tongonito, Enmantecado.* Hot and temperate regions. This species, very common and very numerous as individuals in the hot and temperate lands of the department, rarely goes beyond the height of 1400 metres. Its habit of laying its eggs in the nests of other birds is a fact to which M. de Saussure has already called the attention of naturalists. ("Bibl. Univ. Genève," 1858.)

107. *Sturnella* —? Vulg. *Triguero, Chichilachia.* Hot and temperate regions and plateau. A species of *Sturnella* is very generally distributed throughout the State of Vera Cruz, where, as I think I have sufficient proof, it breeds; not having been able to satisfy myself in regard to the shades which distinguish from each other the species of this form, as described by authors, I only here mention it in passing.

108. *Icterus Wagleri.* Vulg. *Calandria.* Hot region. This belongs to the hot lands of the department, and is quite common in the district of Cordova, to the height of about 1000 metres.

109. *Icterus pustulatus.* Vulg. *Calandria.* Hot region. Belongs to the hottest portions

of the State of Vera Cruz. These two species of Icterus occur from the other side of the western and southern frontiers of the department, that is, from Tehuacan, where they begin to appear, as far as the coast of the Pacific, where they are very common.

110. *Icterus Audubonii.* Vulg. *Calandria.* Temperate region.

111. *Icterus melanocephalus.* Temperate region.

These two *Icteri* have their centre of propagation in the temperate region. They are very common in the district of Orizaba, where they breed.

112. *Icterus Parisorum.* Vulg. *Calandria India.* Temperate and alpine regions. This occurs chiefly in the temperate parts, where it breeds, but is not exclusively confined there, for it is found in the alpine region to the height of at least 1600 metres, near Orizaba, and on the plateau at even a higher elevation.

113. *Icterus cucullatus.* Vulg. *Calandria.* Hot region. This species is rare above an elevation of 600 metres.

114. *Icterus mesomelas.* Vulg. *Calandria.* Hot region. Belongs to the hot country, but passes up to a height of 1000 metres.

115. *Scolecophagus cyanocephalus.* Vulg. *Tordo.* Plateau. Particularly abundant in the plateau, this species rarely shows itself in the valley of the Orizaba except in the winter, and that district is the only locality in which I have found it in the department. It usually comes there in company with another troopial, which is, I believe, the *Molothrus pecoris.*

116. *Quiscalus macrourus.* Vulg. *Tordo.* Hot, temperate, and alpine regions. Common everywhere throughout the department where it nests. In the neighborhood of Cordova and Orizaba, it lives in large communities. A single tree is often loaded with its nests.

117. *Quiscalus Sumichrastii.* Vulg. *Ocho.* Hot and temperate regions. Very common in the hot and in the temperate zone of the department to the height of 1200 metres. It is a bird of the woods, and is less sociable than the rest of its tribe.

In the hot region there is also another *Quiscalus,* the plumage of which is remarkable for the brilliancy of its reflections of violet and purple. I merely mention it here, not having yet been able to determine with certainty to what species it belongs.

118. *Ostinops Montezuma.* Vulg. *Zacua Viuda.* Hot region. Resident in and confined to the hot region of the department, this species rarely ascends to the height of 1000 metres.

119. *Ocyalus Waglerii.* Hot region. I met for the first time this species in the great and virgin forests of Cerra de la Defensa at an elevation of about 900 metres. Its song, like that of the *Ostinops Montezuma* and of the *Cassiculus melanicterus* (the latter from the Pacific coast), possesses a sonorous and metallic ring that throws its sound to a great distance.

120. *Cassiculus Prevostii.* Vulg. *Tordo velox.* Hot and temperate region. Common in the wooded localities of the hot and temperate regions, where it is resident. I think it does not ascend beyond a height of 1000 metres. It does not reach Orizaba.

The *Agelaius phœnicius* (?) is sometimes killed about Orizaba, but I presume it to be only a bird of passage. The *Icterus baltimore* and the *Icterus spurius* are also found in the department, but they are not, to all appearance, resident.

Corvidæ.

121. *Corvus cacalotl?* Vulg. *Cuervo cacalotl.* Alpine region. I refer to this species, so imperfectly characterized, the only representative of the genus that inhabits the department. It is rarely found except within the limits of the plateau, where it is the most abun-

dant. The Cerro Colorado, near Tehuacan, to the south of the State of Puebla, is the rendezvous of a large number of these birds. At the time of the flowering of the Maguey (Agave), with which the sides and summit of that mountain are covered, the Ravens gather there in greater abundance than at any other time. The blossom of the agave is their favorite food, as it is also of other birds, owing to the honeyed sweetness of their corollæ.

122. *Cyanura coronata.* Vulg. *Azulejo.* Alpine region. A resident of the alpine region, this Jay is found as high up as the extreme limits of vegetation on the peak of Orizaba, but is confined to its forests of pines and of oaks. It does not descend lower than 1300 or 1400 metres, and is never seen on the plains. The alpine region also is the exclusive abode of three other species of Blue Jays.

123. *Cyanocitta nana.* Vulg. *Azulejo.* Alpine region.

124. *Cyanocitta californica.* Vulg. *Azulejo.* Alpine region.

125. *Cyanocitta ultramarina.* Vulg. *Azulejo.* Alpine region.

The limit of their extension is about that of the alpine region itself, that is to say, from 1500 to 3500 metres. And a fourth species:

126. *Cyanocitta sordida.* Vulg. *Azulejo.* Plateau and alpine region. This is less exclusively confined to the alpine region, and is also to be found on the plateau.

127. *Cyanocitta ornata.* Vulg. *Azul de toca.* Temperate region. This species, though found in the localities which by their height belong to the alpine region, is rather, more properly speaking, a bird of the temperate region, and among its mountains. It seems to prefer to the forests of pines those more rich in vegetable forms that cover the more elevated portions of the temperate region.

128. *Xanthoura luxuosa.* Vulg. *Verde de toca. Sonaja.* Hot and temperate region. One of the birds most generally diffused throughout the department. It inhabits the hot and the temperate regions, and is found even at the foot of the alpine, to the altitude of nearly 2000 metres.

129. *Psilorhinus morio.* Vulg. *Pepe.* Hot and temperate regions. This bird, so well known and so generally detested on account of its troublesome and noisy habits, inhabits the greater portions of Vera Cruz. It is found everywhere with the exception of the alpine region. It does not appear to go beyond a vertical elevation of 1500 metres. I am assured that this bird never makes a nest of its own, but invariably lays in those belonging to other birds.

DENDROCOLAPTIDÆ AND ANABATIDÆ.

130. *Xiphocolaptes emigrans.* Alpine region. I was very much astonished when, hunting for the first time in the pine forests around Orizaba, I met with the first specimen of this beautiful species. The presence of a form so tropical in appearance at the height of nearly 2500 metres, led me at first to suppose that I had fallen upon a bird driven by some atmospheric perturbation and wandering from its proper abodes, which I supposed from analogy with those of other *Dendrocolaptidæ,* should be the hot region. Several excursions into the same localities put me in possession of so considerable a number of specimens as to demonstrate that my suppositions were unfounded, and to convince me that this bird was a legitimate tenant of the alpine region, and that in all probability it breeds there. It is a bird naturally mistrustful, and is approached with difficulty. With a peculiar persistence on its part quite unusual, it is very rarely that the first discharge of the gun brings it from the

trunk of the tree around which it is creeping. By means of its elongated and strong beak, it readily procures its means of subsistence among the crevices of the bark. I have found in the stomach of one of these birds a tree-frog, *Hyla myotympanum*, which it had probably captured among the tufts of the *Æchmœas epiphytes,* where these reptiles resort during the dry season and even undergo their metamorphoses.

The beak of the *H. emigrans* presents notable differences, according to the sex or age (?) of the individual. In the young bird it is short and but slightly bent. I know not for what reasons the specific name of emigrant has been given to this bird. I feel very sure that those that are found among the mountains of Orizaba are resident there. It would not however be surprising if this species were to be found inhabiting the hot country.

Such a distribution may be cited in regard to: —

131. *Picolaptes affinis.* Hot, temperate, and alpine regions. This bird inhabits the three regions, and in the alpine ascends to the height of at least 2500 metres. Like the *Melanerpes formicivorus* it is especially fond of the oak woods. In the State of Vera Cruz these trees, of different species, seem to characterize it is true, two zones of different temperature and altitude; one situated on the upper confines of the hot lands, the other in the alpine region. It is not surprising that a species (as is the case with this *Melanerpes,* and perhaps with the *P. affinis*) that is resident by choice in the forests of oaks, should appear wherever the abundance of these trees offers the same favorable conditions for their existence.

132. *Glyphorynchus major.* Hot region. Exclusively confined within the limits of the hot region.

133. *Sittasomus sylvioides.* Hot region. Also confined to the forests of the hot country, which it very rarely leaves. It is quite common among the oak woods at Potrero — 590 metres.

134. *Xenops mexicanus.* Hot region. Belonging to the same localities with the preceding.

135. *Synallaxis erythrothorax.* Hot region. Peculiar to the hot region, which it never leaves.

136. *Anabates rubiginosus.* Hot region.

137. *Anabaztenops variegaticeps.* Hot region.

138. *Automolus cervinigularis.* Hot region.

139. *Sclerurus mexicanus.* Hot region. The last four, while they all have their general centre of propagation in the hot region, are also occasionally seen in localities having a greater altitude. This is especially true of Nos. 136, 137, and 139, which are thus found to the foot of the alpine region, at Orizaba, at the height of 1300 metres.

Formicariidæ.

The species belonging to this family found in Mexico as well as in the rest of tropical America, are, for the most part, residents of the moist forests, the soil of which, covered with a thick coating of vegetable mould, mingled with organic debris of all kinds, offers an abundant harvest of insects and larvæ. The eastern portions of the department of Vera Cruz, spoken of in these notes as the hot region, presents, to the few *Formicariidæ* that inhabit it, all the favorable conditions that their organization requires, and there we must chiefly look for them. But the presence of one species of this family in the alpine region, in the midst of the pine forests, proves that these conditions may be met with at any altitude.

140. *Grallaria guatemalensis*? Hot region. This species, if correctly named, without being common in any portion, is found in the hot region of the department. I have seen it at Uvero, near San Andres Tuxtla, at Potrero (590 metres), at Omealca, etc.

141. *Grallaria* ——? Alpine region. I found, a few years since at Moyoapam (2500 metres), one of the most characteristic of the alpine localities, a *Grallaria* exactly resembling in its colors the one which I call, correctly or incorrectly, the *G. guatemalensis*, but of a length much greater than the specimen of the latter that I possess. Is it to be referred to the alpine form of the *G. mexicanus* Scl.?

142. *Formicarius moniliger*. Hot region. This bird lives in the interior of the great woods of the hot region. It is common in those of the Cerro de la Defensa near Potrero, where it reaches the altitude of 800 metres, and perhaps more. By nature it is rather wild. Its cry, when heard at a distance, is a series of ascending notes, not without some resemblance to, though more sonorous than, that of the *Catherpes mexicanus*. It is almost always to be seen on the ground, turning over with its beak the dry leaves or the moss in search of insects. This habit has caused it, in some places, to be called a partridge.

143. *Thamnophilus melanocrissus*. Hot region. An indigenous species of the hot lands, but which is found to the height of 1000 metres in the wooded localities, which it frequents exclusively.

144. *Thamnophilus doliatus*. Vulg. *Granizo*. Temperate region. Very common in the temperate region, where it is found to the altitude of about 1250 metres.

Tyrannidæ.

The geographical distribution of the birds of this family is sufficiently well marked to enable us to recognize at once from the bird itself the region to which it belongs. Certain forms — the genera of *Attila*, *Mionectes*, *Myiobius*, *Platyrhynchus*, etc., are characteristic of the hot region. Others live both in the hot and the temperate regions — *Myiozetetes*, *Milvulus*, *Scaphorhynchus*, *Myiodynastes*; the *Contopus* does not leave the alpine region; others again, such as the *Pyrocephalus*, the *Empidonax*, etc., are cosmopolitan, and are found at all heights. I am obliged, in my enumeration of the species belonging to the department, to omit several with which I am acquainted, but the determination of which has left me in too much doubt to mention them.

145. *Attila citreopygia*. Hot region. Peculiar to the hot region, never rising, as I believe, higher than 500 metres.

146. *Mionectes assimilis*. Hot region. Distribution analogous to the preceding.

147. *Milvulus forficatus*. Vulg. *Tijereta*. Hot and temperate regions. This species is an inhabitant of the hot lands; but a few individuals ascend, though very rarely, to the height of Orizaba, or 1220 metres.

148. *Milvulus tyrannus*. Vulg. *Tijereta*. I do not know that this species is resident. Abundant in winter in the savannahs of the hot lands, and occurring to the height of about 700 metres.

149. *Scaphorhynchus mexicanus*. Vulg. *Portugués-Bientareo*. Hot and temperate regions. Belongs both to the hot and temperate country. Orizaba, or 1220 metres, is the extreme limit of its vertical elevation.

150. *Pitangus Derbianus.* Vulg. *Portugués-Campeador.* Hot and temperate regions. Same distribution with the preceding.

151. *Myiodynastes luteiventris.* Hot and temperate regions. The same distribution.

152. *Tyrannus intrepidus.* Hot region. Quite rare. The specimens I have seen came from the hot lands. I found it a few years since at Ventosa, near Tehuantepec.

153. *Tyrannus vociferans.* Vulg. *Madrugador.* Hot and temperate regions and the plateau. Common throughout the department.

154. *Myiozeletes texensis.* Vulg. *Portugués.* Hot and temperate regions. Throughout the hot and the temperate lands rising to the height of 1400 metres.

155. *Myiarchus mexicanus.* Hot region. I have only met with this species in the hot region.

156. *Myiarchus Lawrencii.* Vulg. *Triste.* Temperate and hot regions. This is a resident species, common to both the hot and the temperate regions.

157. *Legatus variegatus.* Hot region. Confined to the hot region.

158. *Myiobius sulphureipygius.* Hot region. The same habits with the preceding; both live principally in the woods.

159. *Oncostoma cinereigulare.* Hot region. The only specimen of this species that I have been able to procure came from the hot region.

160. *Platyhrynchus cancroma?* Hot region. From the forests of the hot country.

161. *Sayornis nigricans.* Vulg. *Aguador.* Temperate and alpine regions. Very common in the temperate and colder portions of the department. It nests in the houses of Orizaba.

162. *Pyrocephalus mexicanus.* Vulg. *San Gabrielito.* Hot, temperate, and alpine regions. Common everywhere and at all heights.

163. *Contopus mesoleucus.* Vulg. *Tengo frio.* Alpine region.

164. *Contopus sordidulus.* Vulg. *Tengo frio.* Alpine region. These species are both residents of the alpine region, but occur as low down as Orizaba.

165. *Contopus pertinax.* Alpine region.

166. *Contopus virens.* Alpine region. I have found both these species common in the mountains of Orizaba, between 1200 and 2500 metres.

167. *Mitrephorus phœocercus.* Vulg. *Burlista.* Alpine and temperate regions. Not rare in the upper portions of the district of Orizaba, as also in the lower alpine region.

168. *Empidonax pusillus.* Temperate region. I place this bird among the number of resident species from finding it quite common around Orizaba in summer, June and July. I can say the same in regard to a species of *Elania*, probably *E. placens.*

I pass by, without mention, several *Tyrannidæ*, resident within the department, not being entirely assured as to their determination.

The *Sayornis Sayus*, *S. fuscus*, *Empidonax Hammondii*, *E. flaviventris*, and *E. obscurus*, are all found within the department, but I am not able to state whether they are residents or only migratory.

TITYRINÆ.

In regard to this group of birds, we have again to note one of those curious facts such as we have observed in connection with a *Grallaria* (No. 141), and the *Xiphocolaptes emigrans.* I refer to the appearance of types eminently tropical in localities indisputably alpine. We know, in fact, that the *Tityrinæ* belong to the hottest regions of South America, yet in Mexico, of the four species that belong to this group, two ascend to the height of 2500 metres, and are found in the midst of the pine forests in company with the *Junco*, the *Parus*, the *Cyanocitta*, etc. I know not how far this association may be temporary, and whether the presence of a *Platypsaris* and of a *Bathmidurus* within the alpine region, be transient or not. Be this as it may, the fact has seemed to me of sufficient interest to be noted here.

169. *Tityra personata*. Vulg. *Rechinador*. Hot and temperate regions. Common in the hot and temperate portions, not exceeding an elevation of 1200 metres, a little less than that of Orizaba, where it rarely appears.

170. *Erator albitorques*. Hot region. More rare than the preceding species, and confined within the limits of the hot regions. I have never met with it above 600 metres.

171. *Platypsaris aglaiæ*. Vulg. *Saltator*. Hot, temperate, and alpine regions. I am led to believe that there are two varieties of this form in the State of Vera Cruz. The one especially found in the hot and temperate regions, of stouter proportions, and in the adult male at least with darker plumage, etc. The other, which I have met with several times in the alpine region, is appreciably inferior in size to the preceding, and with lighter tints in the adult male. It is possible that to the latter variety, the name of *P. affinis* has been given.

172. *Bathmidurus major*. Hot, temperate, and alpine regions. This name, according to the descriptions before me, appears to belong to all the individuals of the genus *Bathmidurus* that I have observed in the department. While some have been met with in the hot and in the temperate portions, I have killed others precisely similar in the pine woods of the alpine region (Moyoapam, 2500 metres).

Cotingidæ.

173. *Lipangus unirufus*. Hot region. A species characteristic of the hot region, as well as

174. *Manacus candei*. Vulg. *Turquito blanco*. Hot region.

175. *Pipra mentalis*. Vulg. *Turquito*. Hot region. The highest localities in which I have observed these two manikins do not exceed in altitude 600 metres.

I terminate here, with the grand division of Insessores, this analysis of the principal facts relative to the distribution of birds in the State of Vera Cruz. In giving below the list of the birds that characterize each region, I shall add several of other families not mentioned in the preceding pages.

Résumé.

From what has now been said, I infer that the department of Vera Cruz, considered as a zoölogical province, may be divided into three distinct regions, succeeding each other from the east to the west, and each more or less completely characterized by the predominance of certain ornithological forms peculiar to them.[1]

The first of these regions of Vera Cruz, which, in conformity with the usual terms, I call the hot region (*terres chaudes* or *tierras calientes*), extends along the Gulf of Mexico, between the departments of Tamaulipas and Tabasco, and from the eastern border gradually rises to an altitude which we may fix approximately as about 600 metres.

The second or temperate region (*terres tempérées* or *tierras templadas*), extends from the western confines of the preceding to the foot of the Cordilleras, which form the eastern out-

[1] We may further, as it seems to me, consider Mexico as divided into three grand zoölogical provinces — the Eastern, the Central, and the Western, similar to those which Prof. Baird has indicated for North America. (*Amer. Journ. of Science;* on Migration, etc.)

works of the plateau of Mexico. We assign as its limits an elevation from 600 to 1500 metres, or thereabouts.

The third, in the absence of any common term, I propose to call the alpine region, the vague name of *tierra fria*, commonly applied to the alpine region and the great central plateau to designate its climate, being inadmissible in connection with the geographical distribution of the birds. This alpine region embraces the western portions of the department, including all the mountainous portions, between 1500 and 3500 metres in height.

It is quite remarkable that within a territory so circumscribed as that to which these notes are limited, we thus find, represented zoölogically within a space of about 180 kilometres in breadth (taking for our line of observation the route from Vera Cruz to Mexico, and for the extreme points on this line, Vera Cruz at the sea level, and the peaks of Aculzingo, to the height of 2450 metres), the two grand natural divisions designated by naturalists under the names of Regio Nearctica and Regio Neotropica.

The union of the respective faunæ of these two divisions occurs in several localities of the temperate region of the department of Vera Cruz in the most striking manner. The city of Orizaba may be cited as an instance. The locality adjoining this city on the southeast is visited by many forms from the hot region never to be found on the opposite side of the city. I will only name the *Pionus senilis, Cœreba carneipes, Saltator atriceps, Rhamphocelus sanguinolentus, Pitangus Derbianus, Tityra personata*, etc., all of which, at certain periods, come to dwell in the gardens and thickets of the neighborhood of the city on the southeast side; while on the opposite side of the city we first meet with the *Contopus*, the *Pipilo*, and other representatives of the cold region. An analogous meeting may also be remarked in regard to the reptiles: on the one side the tropical forms are restricted to the more protected localities on the southeast of the city (*Ameiva undulata, Cubina grandis, Corythæolus vittatus, Ahætulla mexicana*, etc.), and giving place on the opposite side to the typical species of the cold regions, such as *Sceloporus malachiticus* and *S. scalaris, Plestiodon lynx, Ninia diademata, Ogmius varians, Eutœnia sirtalis, E. proxima*, etc., etc.

It only remains, to complete this paper, to give, for each region, a list of the species that characterize it, either because they never pass from within its limits, or because they there have their centres of propagation, and only accidentally occur in other regions.

Hot Region.

Granatellus Sallæi.
Pitylus poliogaster.
Saltator magnoides.
Lanio aurantius.
Phœnicothraupis rubica.
    rubicoides.
Ramphocelus sanguinolentus.
Tanagra diaconus.
Chlorophonia occipitalis.
Euphonia affinis.
    hirundinacea.
    Gouldii.
Guiraca concreta.
Cyanospiza parellina.
Icterus Waglerii.
Icterus pustulatus.
    cucullatus.
    mesomelas.
Ostinops Montezumæ.
Ocyalus Waglerii.
Glyphorhynchus major.
Sittasomus sylvioides.
Xenops mexicanus.
Synallaxis erythrothorax.
Anabates rubiginosus.
Anabazenops variegaticeps.
Automolus cervinigularis.
Sclerurus mexicanus.
Grallaria guatemalensis.
Formicarius moniliger.

Thamnophilus melanocrissus.
Attila citreopygius.
Mionectes assimilis.
Milvulus tyrannus.
Tyrannus intrepidus.
Myiarchus mexicanus.
Myiobius sulphureipygius.
Oncostoma cinereigulare.
Platyrhynchus cancroma.
Erator albitorques.
Lipaugus unirufus.
Manacus candei.
Pipra mentalis.

We also find among the characteristic birds of the hot region, besides many others, the following species, belonging to other families of birds not mentioned in these notes and the above list: —

Ceryle superciliosa.
Momotus Lessoni.
Hylomanes momotula.
Trogon puella.
caligatus.
melanocephalus.
Massena.
Dryocopus guatemalensis.
Celeus castaneus.
Rhamphastos carinatus.
Pteroglossus torquatus.
Conurus aztec.
holochlorus.
Chrysotis autumnalis.
ochroptera.
Herpetothere cachinnans.
Spizætus ornatus.
tyrannus.
Buteo Ghiesbreghtii.
Asturina nitida.
Rosthramus sociabilis.
Falco femoralis.
Peristera cinerea.
Geotrygon montana.
Lepidænas speciosa.
Crax globicera.
Penelope purpurascens.
Ortalida vetula.[1]
Ortyx pectoralis.
Odontophorus guttatus.
Tinamus robustus.

A glance over the preceding list will enable us to appreciate readily the principal characters, both negative and positive, that distinguish this region : —

First, the inferiority in numbers of the Oscines in comparison with other subdivisions of the Insessores. This inferiority, as we shall presently see, disappears as we advance in height, and in the alpine region we find the Oscines comprising very nearly the whole of the ornithological fauna.

Second, the total absence of the three families of Oscines. *Cinclidæ*, *Paridæ*, and *Certhiadæ;* we might even add, without fear of being too exclusive, two others, *Ampelidæ* and *Laniidæ*.

Third, the small numerical development of certain families very well represented in the other regions, namely, *Turdidæ* and *Fringillidæ*.

Passing from these negative characteristics to those which we may call positive, we may remark in the hot region : —

First, the presence of several families that are very nearly or completely wanting in both the other regions, that is to say, *Momotidæ*, *Pipridæ*, *Psittacidæ* (except *Pionus senilis* of the temperate region, and *Rhynchopsitta pachyrhyncha*, of the alpine region), *Rhamphastidæ* (except *Aulacoramphus prasinus*), and *Penelopidæ* (except *Ortalida*).

Second, the maximum development of certain families essentially neotropical, as the *Tanagridæ*, the *Dendrocolaptidæ*, the *Anabatidæ*, and the *Trogonidæ*.

Third, the presence, in the orders of Accipitres and of Grallæ of several species identical with those of South America, e. g., *Spizætos ornatus*, *S. tyrannus*, *Asturina nitida*, *Rosthramus*

[1] *Ortalida vetula?* is found in both the hot and temperate regions, but is more abundant in the former.

sociabilis, *Falco femoralis*, etc., *Mycteria americana* (I have found this beautiful species near Cosamaloapam), *Cancroma cochlearia*, *Agamia picta*, *Tigrisoma lineatum*, etc.

This identity of species is found, though to a less degree, among the reptiles; among the Ophidians, *Crotalus durissus* Linn., *Bothrops atrox*, *Lachesis mutus?* *Oxybelis acuminatus*, *Herpetodryas Boddiertii*, *Leptodeira annulata*, *Imantodes cencoautl*; among the Batrachians, *Bufo agua*, *Hyla lichenosa*, *Hyla Baudinii* (*fide* Gunther, Catal.). The saurians of the hot region, so far as I know, present no such cases, but they contain several exclusively neotropical genera, e. g., *Iguana*, *Basiliscus*, *Læmanctus*, *Ameiva*. The presence of the genus *Crocodilus* in this region, and the numerical superiority of the Chelonians, are also strongly characteristic.

Temperate Region.

This region is not so well characterized as that to which we have just referred, and it is in many cases difficult to distinguish the one from the other in an absolute manner. Its productions, both animal and vegetable, present a mixed physiognomy which render their geographical distribution uncertain, or at least quite difficult, and it is upon negative characteristics, that is to say, the absence rather than the presence of certain forms, that we must rely for characterizing its peculiarities. Yet positive characters are not entirely wanting, as will be proved by the following list of species, all of which have their principal centres of propagation within the limits which I regard as fixing the temperate region: —

Catharus mexicanus.
Harporhynchus longirostris.
Melanotis cærulescens.
Sialia azurea.
Campylorhyncus zonatus.
Basileuterus culicivorus.
rufifrons.
Bellii.
Euthlypis lacrymosa.
Neochloe brevipennis.
Cyclorhis flaviventris.
Vireolanius melitophrys.
Myiadestes unicolor.
Buarremon albinuchus.
Pyranga bidentata.
erythromelæna.
Chrysomitris mexicana.
notata.
Aimophila rufescens.
Icterus Audubonii.
melanocephalus.
Quiscalus Sumichrasti.
Cyanocitta ornata.
Tyrannus vociferans.
Mitrephorus phœocercus.
Pionus senilis.
Aulacoramphus prasinus.

The *Pionus senilis* does not, properly speaking, belong exclusively to the temperate region. It is, on the contrary, quite common in the hot region; but the fact that it is the only one of the *Psittacidæ* to be found near Orizaba, has induced me to include it here.

In certain localities the *Ara militaris* may also be met with in the temperate region, but I do not think it breeds there.

Alpine Region.

Catharus occidentalis.
Hylocichla Audubonii.
Planesticus migratorius.
Turdus pinicola.
Cinclus mexicanus.
Sialia mexicana.
Lophophanes Wollweberi.
Parus meridionalis.
Psaltriparus melanotis.
Sitta carolinensis.
pygmæa.
Certhia mexicana.
Campylorhynchus pallescens.
Troglodytes brunneicollis.
Parula superciliosa.
Dendrœca olivacea.

Geothlypis speciosa.
Setophaga picta.
Cardellina rubra.
Progne subis.
Vireo Huttonii.
Ptilogonys cinereus.
Myiadestes obscurus.
Diglossa baritula.
Hesperiphona vespertina.
Chrysomitris pinus.
Curvirostra americana.
Junco cinereus.
Atlapetes pileatus.
Guiraca melanocephala.
Chamæospiza torquata.
Pipilo maculatus.
Cyanura coronata.
Cyanocitta nana.
Cyanocitta californica?
ultramarina?
sordida.
Xiphocolaptes emigrans.
Grallaria —— ?
Contopus mesoleucus.
sordidulus.
pertinax.
virens.
Platypsaris ——— ?
Bathmidurus major?
Trogon mexicanus.
ambiguus.
Picus Harrisii.
Colaptes mexicanus.
Rhynchopsitta pachyrhyncha.
Chlorœnas fasciata.
Dendrortyx barbatus.

The presence of two species of Trogon, and that of a representative of the tropical family of *Psittacidæ* in the alpine region, in the midst of its forests of pines, is certainly a curious fact, and one in regard to which no explanation may be ventured.

Additional Notes.

Cypselidæ. — Three species of this family are resident and breed within the State of Vera Cruz. These are the *Chætura rutila*, *Nephœcetes niger*, and *Chætura zonaris*. The *Chætura semicollaris* Sauss., is not found. In 1856, I killed, near Mexico, several specimens, upon which the species was established, but I have not met with them since. I think that I have recognized the *Panyptila melanoleuca* in a species from the mountains of Orizaba; another species abundant in the Valley of Mexico, where it is seen flying over the water, seems to me to answer to the description of the *Chætura pelasgia* (or *Vauxii?*).

In an article on the habits of various birds of Mexico, published in the "Bibliothèque Universelle de Genève," M. de Saussure attributes to the *Colaptes mexicanus* the instinct of storing up collections of acorns in the hollow trunks of the Maguay. While recognizing

the entire truth of the interesting facts narrated in this article, as I accompanied the author in his excursions to Pizarro, I think that the bird to which we should assign the credit of this instinctive forethought is not the *Colaptes*, but the *Melanerpes formicivorus*. The latter dwells exclusively in oak woods. Near Potrero (Cordova), as well as in the alpine region, we find the trunks of oak trees pierced with small holes in circular lines around their circumference. Into each one of these holes this bird, by repeated blows with its beak, drives the acorn, so as to fix it firmly. At other times, as we see in the sketch, these woodpeckers make their collections of acorns in openings within the raised bark of dry trees. I have in vain sought an exact explanation of the use made by these birds of this performance. We might suppose, were the locality destitute of insects, that the birds were in quest of the larvæ contained in the acorns; but can we imagine them taking all this pains in localities teeming all the season with insects? And can we suppose a desire for larvæ of almost microscopic proportions to be the motive that prompts these birds to labor whole hours at a time in cutting into the hard envelope of the oaks? However inconceivable this explanation may appear, it is yet the one that seems to have been most generally adopted. In regard to this fact, as cited by M. de Saussure, it is not at all surprising that he should have attributed this perforation of the Maguay to the *Colaptes mexicanus,* since this bird is found at Pizarro in company with the *Melanerpes formicivorus.*

Published March, 1869.

XVII. *The Eruption of the Hawaiian Volcanoes*, 1868. By William T. Brigham, A. M.

Read December 16, 1868.

Those who are familiar with the phases of volcanic activity on the Hawaiian Islands, have noticed the rare occurrence of severe earthquakes on this group, at least in modern times. Indeed, one of the most marked features of an eruption of either Hualalaì, Mauna Lòa, or Kilauéa, has been the silent, unannounced outflow of lava. The struggling floods of molten rock have forced an outlet without disturbing the portion of the mountain not in their path, so that dwellers at the very base of the gigantic cone of Mauna Lòa have seen the bright glare of the lava descending the slopes, while neither noise nor trembling of the earth could be perceived. This has been true of all eruptions since 1801, but at some former period severe convulsions have greatly disturbed the beds of lava which form the substratum of the whole island of Hawaii, and most especially in the district of Ka-ù, which includes all the southwestern portion of this island. From Manukà to Kahúku the road passes over deep clefts formed by the tearing asunder of the rock, often to a distance of twenty feet. These rents are found as well farther on toward Kápapala, but generally of smaller size, although between the latter place and the sea the ground is greatly broken up.

Since 1865 the great crater of Kilauéa has been slowly filling up by the overflow of the northern lakes of 1864, and various cones between these and Halemáumau (see Map, Plate XV), until the whole central portion was considerably elevated, nearly double the height represented in the section of Kilauéa on the map referred to. Mauna Lòa also has been more or less active since visited by Mr. Horace Mann and myself in 1865. Then the great summit crater Mokuawéowéo was quite still, and apparently cold and extinct, exhibiting hardly any signs of more recent action than does Háleakala, on the island of Máui; only on one of the lower walls a little steam floated up from the cracks below. No one has ascended this mountain since our visit three years since, but from the shores the glare of its crater has been distinctly seen more than once in the interval. As it was winter, and the snows and storms rendered the ascent dangerous, no one attempted it, and as no lava stream flowed down, little attention was paid to these distant and temporary volcanic displays.

During the past ninety years, ten great eruptions have taken place on Hawaii, averaging one for every nine years, the last occurring in 1859, when a large stream of lava flowed some sixty miles, into the sea. The lava had accumulated in the reservoirs which supply Mauna Lòa, and was ready to break forth. To this brief statement of the condition of the Hawaiian volcanoes previous to the present outbreak, may be added the fact that the season had been exceedingly rainy; great quantities of rain had fallen on Hawaii, and the mountain streams were much higher than usual.

March 27th, 1868, about five and a half o'clock A. M., persons on the whale ships at anchor in Kawaihàe harbor saw a dense cloud of smoke rise on the top of Mauna Lòa, in one massive pillar, to the height of several miles, lighted up brilliantly by the glare from the crater Mokuawéowéo. In a few hours the smoke dispersed, and at night no light was visible.[1]

About ten o'clock A. M. on the 28th (Saturday), a series of earthquakes began, which have

[1] Rev. J. D. Paris writes from Kóna, on the western side of the island, that "in less than half an hour these columns of smoke had shot up along the slope of the great mountain [Lòa] southward to the distance of ten or fifteen miles. We thought it was from a stream of lava . . . but the clouds soon shut in the whole mountain, and nothing more was seen during the day. . . . During the whole night no light nor smoke were to be seen. All was clear, and still as death."

continued at intervals nearly eight months. The shocks commenced early in the morning; the first was followed at an interval of an hour by a second, and then by others at shorter intervals and with increasing violence, until at one o'clock P. M. a very severe shock was felt all through Ka-ù and Kóna, the districts which have suffered most by these disturbances. From this time until the 10th of April the earth was in an almost constant tremor. In the district of Kóna as many as fifty or sixty distinct shocks were counted in one day; in Ka-ù over three hundred in the same time; while near Kilauéa and about Kápapala it was difficult to count them. It is said that during the early part of April two thousand distinct shocks occurred in Ka-ù, or an average of one hundred and forty or more each day. The culminating shock occurred on Thursday, April 2d, at twenty minutes before four in the afternoon. Every stone wall, almost every house, in Ka-ù, was overturned, and the whole was done in an instant. A gentleman riding found his horse lying flat under him before he could think of the cause, and persons were thrown to the ground in an equally unexpected manner. Mr. F. S. Lyman was at Keàiwa, near the point where the motion was greatest, between that and the centre of vibration, which was not very distant, as the angle of emergence was almost 90°, or nearly coincident with the seismic vertical, and he reports as follows: —

"First the earth swayed to and fro north and south, then east and west, round and round, then up and down and in every imaginable direction, for several minutes; everything crashing around us; the trees thrashing about as if torn by a mighty rushing wind. It was impossible to stand, we had to sit on the ground, bracing with hands and feet to keep from rolling over. In the midst of it we saw burst out from the pali, about a mile and a half to the north of us, what we supposed to be an immense river of molten lava (which afterwards proved to be red earth), which rushed down its headlong course and across the plain below, apparently bursting up from the ground, throwing rocks high in the air, and swallowing up everything in its way, trees, houses, cattle, horses, goats, and men, all in an instant, as it were. It went three miles in not more than three minutes' time, and then ceased. Some one pointed to the shore, and we ran to where we could see it. After the hard shaking had ceased, and all along the sea-shore, from directly below us to Punalúu, about three or four miles, the sea was boiling and foaming furiously, all red, for about an eighth of a mile from the shore, and the shore was covered by the sea. We went right over to Nahala's hill with the children and our natives, to where we could see both ways; expecting every moment to be swallowed up by the lava from beneath; for it sounded as if it was surging and rushing under our feet all the time, and there were frequent shakes. In places the ground was all cracked up, and every rock or pali that could fall had fallen. At Hiléa we saw a small stream of black smoking lava, and outside of Punalúu a long black point of lava slowly pushed out to sea and soon disappeared."

Ten miles to the southwest of Keàiwa, at Waiohínu, the great stone church was levelled to the ground, and nearly all the other buildings were destroyed. The earth opened all through the district, and often left dangerous fissures, although it usually closed. The meizoseismic curve (or that of maximum overthrow) seems to have been elliptical, with a major axis of about ten miles in a southwest and northeast direction, while the isoseismic curves were rather crescent shaped, having their convexity towards Mauna Lòa. The plain between the mountains of Hawaii contains a structure well adapted to indicate the direction, force, and emergence of an earthquake wave — the Temple of Umi, but no one has yet observed this. In Kóna the shocks were severe, but less so than in Ka-ù; at Koháḷa they did very little damage, not even injuring the tall chimney of the Koháḷa sugar-mill; while at Hìlo, on the other side of the mountains, the violence of the vibrations was about the same as in Kóna. The mountains seem to have deadened the shock, and simply transmitted it through their solid cones to the axes of the other islands of the group, where the shock of April 2d was felt as a vibration from the central mountain to the sea. This was the case even in Kauaì, nearly three hundred miles distant from the supposed seismic vertical. No damage was done except in these southern districts of Hawaii, where the undulations seemed to bend around the base of the mountain, forcing the isoseismic curves far from the meizoseismic curve in Ka-ù.

At Hìlo, although the shock was not so severe as at Waiohínu, more damage was done, for the houses were both larger and more numerous. A correspondent writes: "I was coming from the tannery to my store, when I heard a loud rumbling noise like a number of iron carriages drawn over a rough road by wild horses. Soon the shock came. The horses in the pasture took fright, and ran and snorted, the dogs howled, and the pigeons flew about as if somebody had been shooting at them. The shock lasted a good while, how long I cannot say, but long enough to make me feel sea-sick, and it was with difficulty that I could stand. All the stone walls about the town were flat." Fissures opened, and the brooks ran mud; in one place a fissure opened about a foot, and when it closed the two sides were several inches from coincidence.

The land-slide referred to by Mr. Lyman, is well described by the Rev. T. Coan, whose letter will be given presently. The most destructive feature of the whole catastrophe, however, was the sea-wave which swept the shores of Hawaii from Kahúku to Kapóho, and was sensibly felt at the most distant shores of the group. At Hìlo the sea receded a hundred and fifty or two hundred feet, and when it returned rose about ten feet above high water-mark. Along the shore between Kapóho and Kalàe, villages were swept away, and even heavy stone houses disappeared before the destroying waves.

The earth continued to vibrate, but the shocks were not very severe until on Tuesday night, April 7th, lava broke out in Kahúku, and flowed some ten miles into the sea. The exact locality of this flow was afterwards determined by Mr. Coan.

The schooner "Oddfellow" was cruising along the coast of Hìlo, Púna, and Ka-ù, about the time of the sea-wave and the eruption, and from the report of a passenger the following notes are extracted. As she touched at many points, the information is of considerable interest.

"Saturday, March 28. Lakes in Kilauéa active. Portion of the southwest cliff thrown down. Sunday, 29. Shakes frequent, but slight; one of them very peculiar in its motion, commencing from northwest to southeast, shook a moment, and then shifted to northeast and southwest. North lake quite active. Shocks appear to have been stronger on the beach at Keauhóu than they were at the volcano. Thursday, April 2. Severe shock at Hìlo. Keauhóu and other villages in the neighborhood swept away. Friday, 3. Shocks very violent in Kilauéa. Fire in Poli-o-Keàwe, the south lake terribly active, and enlarging rapidly. Saturday, 4. Saw fire on the hills at Kapóho; could not tell whether it was a lava flow or not. Sunday, 5. Made Kealakómo, Púna, at daylight. The houses nearest the beach gone; the same at Kahue. All swept clean at Apùa. Reached Keauhóu, Ka-ù, at seven A. M., and anchored. Found the anchorage and boat-landing all right. Every building, eleven in all, washed away; not a stick or stone of them left standing. Portions of the wreck washed inland over the flat about eight hundred feet; heavy ohia sticks and a large spar were carried that distance. In some places the ground appeared to have sunk, and the sea was flowing a fathom deep where houses formerly stood. Men who were at work near the beach at the time of the shock (April 2), say that the walls of stone buildings were thrown outward by the shock, which was so severe that they were themselves thrown off their feet; then the sea came pouring over the rocks which lined the shore, and they escaped being overtaken, by the hardest kind of running. No one was hurt. A messenger from Kilauéa reports that hardly a sign of fire was to be seen in the crater. Got under way and ran down to Punalúu. Monday, 6. Too rough to attempt a landing. The stone church and all the other buildings near the sea gone. At Ninole but three houses were left. Smoke or steam is issuing from the hills back of Hiléa. Came to anchor at Kaáluálu at noon. The houses, wharf, etc., all gone here, and the rocks inland strewed with the wreck for a distance of six or eight hundred feet. Dense clouds covered the summit of Mauna Lòa, but no sign of fire, and no reflection from Kilauéa. Tuesday, 7. The deck covered this morning with very fine ashes. Procured animals, and rode along the beach to the south point. The sea had been inland in some places a hundred and fifty yards, and the whole coast was lined with house timbers, lumber, broken canoes, dead animals, etc., that had drifted ashore. At Halii found the body of a native woman, lying among the rocks, the right leg bitten off at the knee, and the body otherwise horribly mutilated by the sharks. The shock of the earthquake was evidently slight in this direction, for many of the stone pens were not much damaged, and at Kalàe, the extreme southerly point, there was no sign of any disturbance. Weighed anchor at three P. M., and ran past Kalàe. At six P. M., when the point was about ten miles astern, bearing E. by S., a volume of smoke and flame shot up from the mountain [Lòa], in what appeared to be the neighborhood of Kahúku. The heavens were lighted up at once, and the reflection extended rapidly in the direction of Waiohínu and Kaáluálu. After the first outburst we saw the fire but once or twice, and then it appeared to be the grass burning on the edge of the cliff, which extends inland from the south point. There was no flow of the lava over the cliff, nor toward Kóna, and the stream probably ran down on the Kahúku flat, or between there and Waiohínu to the neighborhood of the Kaáluálu landing. It reached the sea somewhere in that direction at nine and a half P. M., when an immense body of steam at once arose, through which flashes resembling lightning were constantly darting as long as we were in sight. The top of the mountain was concealed by the dense clouds of smoke."

From a schooner at anchor off Lanai the light of this lava stream was seen about midnight, over the mountain, while flashes like chain-lightning shot up into the clouds. From Lahaìna the same light was seen, and the next day a column of smoke in the same direction. From Kóna the light was first seen about eleven P. M. The Rev. S. E. Bishop, President of Lahainalùna Seminary, on Máui, contributes the following observations: "During the night of April 7th, a bright but varying crimson light over the volcano was visible from the Seminary at the distance of one hundred and twenty statute miles, as measured on Wilkes' chart. This light was a reflection from a mass of cumulus cloud through which vivid lightning was constantly darting. After daylight and through the morning of the 8th, this stupendous column of cloud was visible pouring rapidly up to the ether, with ever varying shape. It was usually well defined on the westward side, where it, at times, presented a perpendicular wall of miles in height. On the east it was ill-defined. Above, it often spread out, especially toward the east, as if borne off by the southeast wind of the upper air. The base, so far as visible, appeared to be commingled with murky brown strata.

"The apparent altitude of this cumulus above the horizon, when at its highest was 3° 30′, which, reduced for a base of 120 miles with 500 feet altitude of the point of observation, gives a height of 7.8 miles. This morning, the 9th, our atmosphere is charged with smoky haze, and a very distinct odor of sulphurous acid."

At Kápapala, on the 7th, the ground was still in violent agitation, with a long undulatory motion. At night a very large flow of lava was seen running down the mountain to the sea. The next day smoke was seen issuing from fissures in this neighborhood.

Mr. H. M. Whitney visited the scene of the eruption on the 10th, and from him we learn the following particulars: "As we approached the flow the rumbling noise became more and more distinct. The ground was covered with what appeared to be cinders, but on examining them we found they were fragments of [basaltic] pumice-stone which had been carried by the wind a distance of over ten miles. Mixed with these cinders was *Pélé's hair*, which we found floating in the air, and when it was thick we had to hold our handkerchiefs to our nostrils to prevent inhaling it; our clothes were frequently covered with it. We hurried on and reached the flow shortly after noon, when from a ridge to the west of it the whole scene opened before us. Between us and the crater was a valley five hundred yards wide and ten miles long, which had recently been overflowed throughout its entire width and length from the mountain to the sea, where it widened to two or three miles. The lava was of the smooth or pahoehoe variety, from ten to twenty feet deep, and partially cooled over, though flames, smoke, and gas escaped from numerous crevices. On Tuesday afternoon, April 7th, at five o'clock, a new crater, several miles lower down than that referred to, and about two miles back of Captain Brown's residence, burst out. The lava stream commenced flowing down the beautiful grass-covered plateau, towards and around the farm-house, and the inmates had barely time to escape with the clothes they had on; the path by which they escaped was covered with lava ten minutes after they passed over it.

"On ascending the ridge we found the eruption in full blast. Four enormous fountains, on a line a mile long, north and south, were continually spouting up from the opening. These jets were blood-red and yet as fluid as water, ever varying in size, bulk, and height. Sometimes two would join together, and again the whole four would be united, making one continuous fountain a mile in length. From the lower end of the crater, a stream of very liquid, boiling lava flowed out and down the plateau, a distance of two or three miles, then following the road ran down the precipice at an angle of about 30°, then along the foot of the pali or precipice, five miles to the sea, the stream being about eight or ten miles in length, and in some places half a mile wide. One peculiarity of the spouting was that the lava was ejected with *a rotary motion*, and as it ascended both lava and stones rotated always in one direction towards the south. This was the only stream which reached the sea, and flowed into it at Kailikìi. It lasted only five days, the eruption ceasing entirely on the night of the 11th or morning of the 12th. During its continuance, the atmosphere was filled with smoke so dense that the sun appeared like a ball of fire, and the whole island was shrouded in darkness. This smoke came from the rent or crater, and was highly charged with sulphur.

"As the lava entered the sea, clouds of steam and smoke rose up, and flames of bluish fire were emitted, rising from the water to a height of from ten to twenty feet. During the night we were at the volcano, the air was highly charged with sulphurous gas and electricity, and frequent flashes of lightning were seen directly over the lava stream, accompanied with short claps of thunder. These flashes were also observed less frequently further up the mountain. About four thousand acres of good pasture land were destroyed, besides which the lava ran over an immense district of worthless land.

"On the night of the 6th of April, prior to the eruption, there was a shower of ashes and pumice-stone, which came from this crater, and covered the country to the distance of ten or fifteen miles, each way. Generally the ashes were not more than one or two inches in depth, but in some places were found to be fifteen. The pumice-stone was very light, and appears to have been carried by the wind a great distance. Pieces two and three inches in diameter floated ashore at Keálakeakùa, forty-five miles distant."

During the early part of April an observer in Kóna kept a careful record of the principal shocks felt there, but in other places no observations were made. The only certain thing, among various and somewhat extravagant reports, is that the vibrations were very frequent and not very severe. In some places they were almost silent, but usually accompanied by subterranean detonations and rumblings, with a noise as of boiling, surging waves in the bowels of the earth. No observations were made on the gases said to have been emitted from some of the fissures.

A LIST OF EARTHQUAKES FELT AT SOUTH KÓNA, DURING THE EARLY PART OF APRIL, 1868

OBSERVED BY REV. C. G. WILLIAMSON.

At 1.45	A. M.	***	*Wednesday*, April 1st.	At 12.37	A. M.	*	
5.40	"	***		12.40	"	*	
6.00	"	*		12.43	"	**	At 1 A. M. a heavy rain came
8.15	P. M.	**		12.53	"	**	on and no shock was felt for
8.30	"	**		9.40	"	*	some hours.
9.21	"	**	Rather harder than last.	2.45	P. M.	*	
10.25	"	***		3.40	"	▬	Terrific shock. This was felt
10.53	"	**	With the sound of an explosion.	4.15	"	**	all over the group, but most
11.00	"	***	With the sound of an explosion.	4.25	"	**	severely in Ka-ù and Kóna.
11.08	"	***	" " very severe.	5.09	"	*	
11.10	"	**		5.45	"	*	
11.12	"	***		5.48	"	*	
11.14	"	***		5.50	"	**	
11.16	"	*		5.57	"	**	
11.18	"	**		6.27	"	**	
11.19	"	**		6.32	"	*	
11.26	"	**		6.40	"	**	
11.29	"	**		8.07	"	**	Rather hard.
11.30	"	**		9.45	"	**	
11.31	"	***	From 11.31 to 11.50 continued	10.06	"	*	
11.50	"	***	explosions followed by shock	11.03	"	**	Harder than the last.
11.51	"	***	of moderate severity. The	12.24	A. M.	**	Rather severe.
12.06	A. M.	*	same from 11.51 to 12.	1.05	"	*	*Friday*, April 3d.
12.18	"	*	*Thursday*, April 2d.	1.25	"	**	
12.20	"	**		1.45	"	***	Harder than usual.
12.35	"	***		2.33	"	***	

At 5.45 A. M.	***	
6.05 "	*	
7.44 "	**	
8.32 "	*	
11.02½ "	*	
4.20 P. M.	*	
5.43 "	*	
6.02 "	*	
6.15 "	*	
7.06 "	*	
7.35 "	}	Explosions, vertical, without shocks.
7.47 "	}	
7.53 "	*	
8.25 "	**	
8.33 "	**	
9.25 "	***	
11.53 "	***	
12.07 A. M.	***	*Saturday*, April 4th.
12.12 "	***	Very hard, as was the last.
12.29 "	***	Harder yet.
12.45 "	***	
4.40 "	*	
5.55 "	*	
6.33 "	**	
7.14 "	*	
10.15 "	**	
2.01 P. M.	**	
2.09 "	**	
5.55 "	**	
8.51 "	**	There were three shocks between Saturday and Sunday, but the time was not noted.
——		
——		
——		
3.35 P. M.	*	*Sunday*, April 5th.
3.55 "	*	
6.44 "	**	
7.25 "	**	
7.30 "	*	
8.11 "	*	Very slight.
9.45 A. M.	*	*Monday*, April 6th.
1.59 P. M.	*	
2.34 "	**	
2.53 "	***	
4.09 "	*	
4.10 "	*	
4.15 "	*	
4.17 "	*	
4.18 "	*	
4.21 "	*	
4.24 "	*	
4.33 "	*	
At 6.00 P. M.	*	Very slight.
6.10 "	**	
7.29 "		An explosion; no movement.
7.54 "	*	Very slight.
8.50 "		Explosion and shake.
8.54 "		Explosion and shake.
9.47 "	*	
9.58 "	*	
1.00 A. M.	*	*Tuesday*, April 7th.
1.15 "	*	
2.10 "	***	
3.55 "	**	
4.00 "	**	
4.08 "	**	
4.20 "	*	
4.40 "	**	
5.00 "	***	
5.45 "	*	
6.00 "	*	
11.16 "	*	
11.33½ "	**	
12.00 M.	**	Rather harder than last.
12.06 P. M.	**	Same as preceding.
12.09 "	**	Same as preceding.
12.13 "	*	
12.20 "	*	
12.55 "	*	
1.02 "	*	
1.50 "	*	
1.57 "	**	Rather hard.
2.00 "	*	
2.18 "	***	
2.54 "	*	With an explosion.
3.08 "	*	
3.11 "	*	
3.12 "	**	
3.17 "	**	
3.20 "	**	
3.32 "	*	
3.41 "	**	
4.00 "	**	
4.07 "	*	
4.08 "	*	
4.20 "	**	Rather hard.
4.32 "	*	
7.26 "	***	
8.21 "	**	
10.33 "	*	
11.05 "	***	
5.30 A. M.	***	*Wednesday*, April 8th.
6.15 "	**	*Friday*, April 10th.

When the eruption of lava was made known at Honolulu, many residents at once set out for Hawaii, and among them a gentleman of distinguished attainments in botany, Dr. William Hillebrand, who has given us so accurate and full an account of what he saw in passing through the disturbed region that it seems worthy of a more permanent record than would be its lot in the local newspaper in which it first appeared. He writes as follows: —

"I started from Hìlo with a few friends for Kilauéa, April 17th; descended the crater on the 18th; examined the extensive fissures near the Púna road on the 20th; the so-called mud-flow on the 21st; and the lava stream in Kahúku on the 23d. On the 24th we crossed the lava stream on the road to Kóna, and reached Keálakeakùa Bay on April 26th.

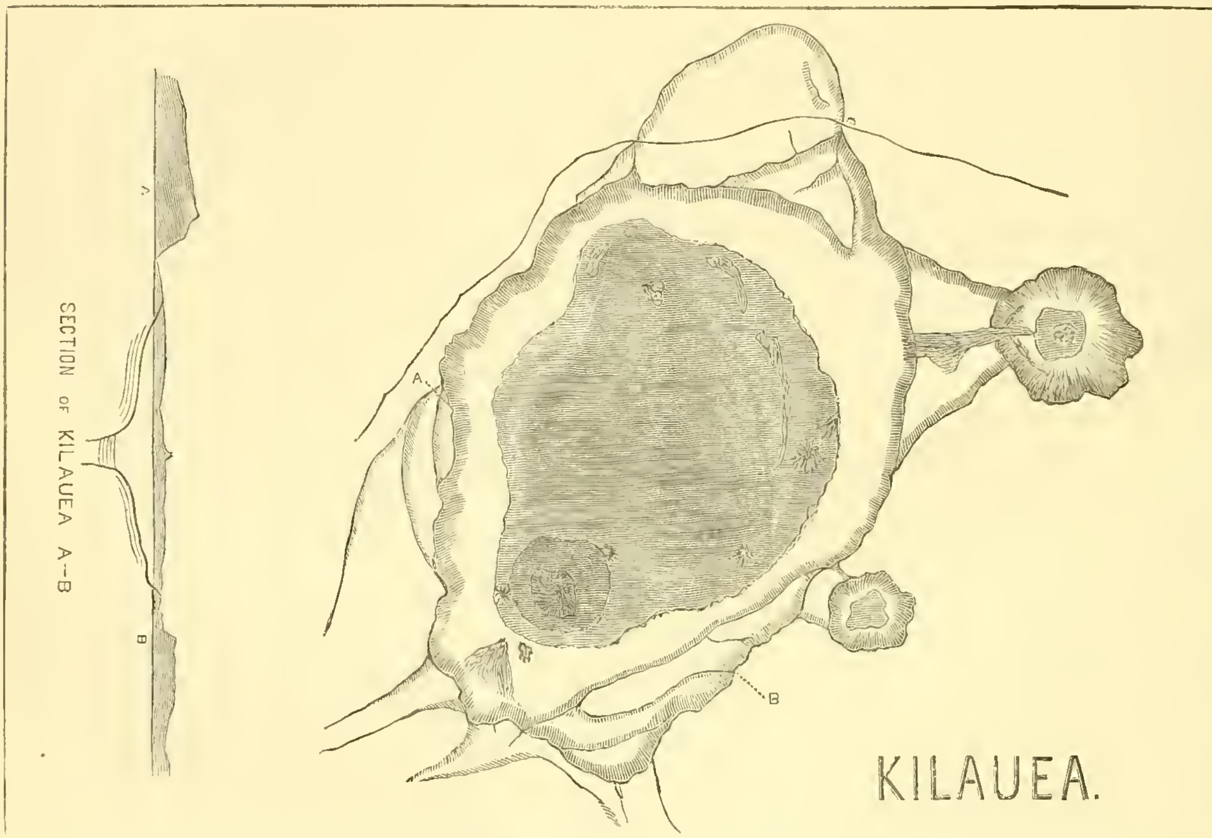
"Of Hìlo, I have little to say, as your correspondents have communicated to you the most remarkable events from that place. I saw several fissures in the earth near Wahiawà River, of from eight inches to one foot in width, which were caused by the earthquake of April 2d, and run in the direction of Mauna Lòa. The earthquake waves all moved from southwest to northeast, and overturned movable objects standing at right angles with that line. A heavy book-case in the Rev. T. Coan's library, holding that relation to the wave, was overturned, while another heavy case, filled with shells and minerals, which stood parallel to the wave, remained standing.

"*Kilauéa.* The ground around the crater, particularly on the eastern and western sides, is rent by a great number of fissures, one near the Púna road more than twelve feet wide, and very deep; others of lesser size run parallel to and cross the Ka-ù road, so as to render travel on it very dangerous. The lookout house is detached from the main land by a very deep crevasse, and stands now on an isolated, overhanging rock, which at the next severe concussion must tumble into the pit below. Many smaller fissures are hidden by grass and bushes, forming so many traps for the unwary." It will be seen by reference to Plate XV, that the northern bank, on which the lookout hut was built, and where these fissures have opened, is much lower than the western walls, and than the ridge on the east where the Volcano House now stands; that it has either been at some time the actual bed of the crater, or has been depressed in a body, suffering from this change of level, or as seems more probable, by commotions like the present, the great dislocations which are indicated on the plan as steam cracks. It will also be seen that the usual path into the crater passes over a portion of the wall which has been much disturbed. This is referred to by Dr. Hillebrand below.

"The Volcano House, however, has not suffered, nor is the ground surrounding it broken in the least. From the walls of Kilauéa, large masses of rock have been detached and thrown down. On the west and northwest sides, where the fire had been most active, before the great earthquake of April 2d, the falling masses probably have been at once melted by the lava and carried off in its stream, for the walls there remain as perpendicular as they were before; but that this part of the wall has lost portions of its mass, is shown too evidently by the deep crevices along the western edge just spoken of, and the partial detachment in many places of large prisms of rock. But it is on the east and northeast wall particularly, that the character of the crater has undergone a change. Along the descent on the second ledge large masses of rock, many, more than one hundred tons in weight, obstruct the path and form abutments to the stone pillars — small buttress hills similar to those observed in front of the high basaltic wall of Koolaù, Oáhu. So also in the deep crater itself the eastern wall has lost much of its perpendicular dip, and has become shelving in part.

"The crater itself was entirely devoid of liquid lava; no incandescence anywhere; pitchy darkness hovered over the abyss the first night. I say the first night, because during the second night of our stay, between twelve M. and one A. M. detonations were heard again, and light reappeared for a short time in the south lake [Halemáumau]. White vapors of steam issued from the floor in a hundred places, but of those stifling sulphurous and acid gases, formerly so overpowering in the neighborhood of the lakes and ovens, only the faintest trace was perceived here and there.

"The heat was nowhere so great that we could not keep our footing for a minute or more, although in many places it would forbid the touch of the bare hand. The great south lake [Halemáumau] is transformed into a vast pit, more than five hundred feet deep, the solid eastern wall projecting far over the hollow below, while the remaining sides are falling off with a sharp inclination, and consist of a confused mass of rough aa. More than two thirds of the old floor of Kilauéa has caved in, and sunk from one hundred to three hundred feet below the level of the remaining floor.



The Crater of Kilauéa after the Eruption, 1868.

"The depression embraces the whole western half, and infringes in a semicircular line on a considerable portion of the other half. This is greatest in the northern, and rather gradual and gentle in its southern portion. Entering upon the depressed floor from the southern lake, it was some time before we became fully aware of its existence, and it was only on our return from the northwest corner, where it is deepest, that there presented itself through the mist in which we were enveloped, a high wall of three hundred feet, grotesque and fanciful in outline. At first we were quite bewildered, fancying that we beheld the great outer wall of the crater. On nearer approach we soon satisfied ourselves that this singular wall represented the line of demarcation of a great depression in the floor of the crater — a fact that surprised us the more, as a bird's-eye view from above had altogether failed to apprise us of its existence.

"As we had been informed that the principal activity of the crater before the great earthquake had been in the northwest corner, we proceeded in that direction on leaving the south lake. Having arrived at about the middle of the depression, a considerable rise in the ground presented itself on our left — to the west. Having ascended this, we found ourselves at the brink of a fearful chasm, which fell off on our side with a beetling wall to the depth of several hundred feet, and extended about half a mile from north to south. Very hot air rose from it. Around it, towards its northern extremity, the lava is thrown up into an indescribable confusion; pile upon pile of aa, gorge and ridge by turns.

"The caving in of the floor seemed to be still in progression, for twice during our exploration of the crater, our nerves were disturbed by a prolonged heavy rumbling and rattling noise, as from a distant platoon-fire of musketry, coming from the northwest corner."

Poli-o-Keàwe, which in 1865 was covered with shrubs on its side and [partly on the] bottom, was now overflowed with black, shining lava. It has been free from fire since 1832.

"Thus far as to what we have seen. Now allow me to relate what I learned from Kaina [the District Judge, and a most intelligent Hawaiian], who has resided near the volcano without interruption for the last five months, and whose strong nerves sustained him during the fearful catastrophe introduced by the earthquake of April 2d. He and the Chinaman who keeps the house, were the only persons who remained at Kilauéa. He says that for two months preceding the first shock, namely, from January 20th to March 27th, the crater had been unusually active; eight lakes being in constant ebullition, and frequently overflowing. During all this time (the date of its first appearance could not be ascertained exactly), there was in the northwest corner a 'blow-hole,' from which, at regular intervals, of a minute or less, with a roaring noise, large masses of vapor were thrown off, as from a steam-engine. This ceased about the 17th of March. At the same time the activity of the lakes became greatly increased, and Kaina anticipated mischief. March 27, the first shock was perceived. Two days later, Mr. Fornander found the bottom of the crater overflowed with fresh lava, and incandescent.

"Thursday, April 2d, at a few minutes past four, P. M., the big earthquake occurred, which caused the ground around Kilauéa to rock like a ship at sea. At that moment, there commenced fearful detonations in the crater; large quantities of lava were thrown up to a great height; portions of the wall tumbled in. This extraordinary commotion, accompanied with unearthly noise and ceaseless swaying of the ground, continued from that day till Sunday night, April 5th, but *from the first the fire began to recede.* On Thursday night, it was already confined to the regular lakes; on Saturday night, it only remained in the great south lake, and on Sunday night there was none at all; Pélé had left Kilauéa. The noises now became weaker, and were separated by longer intervals. By Tuesday, quiet reigned in Kilauéa. On that afternoon, the lava burst out at a distance of forty miles, southwest, in Kahúku.

"April 2d, from six to ten, P. M., Kaina observed fire in the direction of Púna, which, at the time, caused him to believe that the lava had found a vent again in that direction, as it did in 1840; but he subsequently satisfied himself that it was only a reflection from lava in Poli-o-Keàwe. It was not seen afterward.

"In Kápapala we were told that fire had been seen several nights in a southeast direction, and that natives had reported flowing lava there. We rode over in the morning of April 20th. At a distance of five miles from Mr. Reed's dwelling, where the Púna road turns off from the Kilauéa road, heavy clouds of white vapor were seen to issue from the bush, which sparsely covered the pahoehoe, makai[1] of the road. Half an hour's ride brought us up to the place, but we were obliged to leave our horses some distance before reaching the spot, on account of fissures. After having crossed a number of them, heading for the heaviest cloud of vapor, we at last came to a deep crevasse in the pahoehoe, at least twenty-four feet in width, no bottom visible. It narrowed and widened out in places, but nowhere was less than eight feet wide. Its length we estimated at four hundred feet. Parallel with this great crevasse, constituting a belt about six hundred feet in width, were a number of smaller ones on each side, diminishing in size with distance from it, from six feet to a few inches. From the larger openings in the former, heavy white columns of hot steam issued, which had a decidedly alkaline smell. Smaller jets of vapor, to the number of thirty, rose from the smaller fissures. We could not discover fire in any place. but it is very probable that during dark nights the reflection of the underlying lava should be thrown up, for as the steam did not seem to contain combustible material, it is unlikely that the light seen should have been produced by it. The mean direction of all the fissures was N. E. 9° N., S. W. 9° S., or nearly the direction of a line connecting Kilauéa with Waiohínu and Kahúku. The distance of these fissures from Kilauéa is thirteen miles.

"As in this district the earthquake of April 2d culminated to its greatest intensity, so as even to rend in twain the frame-work of a mountain-side, and hurl down on the plain a portion of its flank, it is necessary to give a short description of the country in order to insure a proper understanding of the disturbance. The locality in question is that comprised between the ranch stations of Messrs. Reed and Richardson, on the east, and Mr. F. S. Lyman, on the west, a distance of five miles. The government road connecting these two places runs through a fine grassy plain, which has a very gentle fall towards the sea, its elevation being about 2,000 feet. Into this plain project from the slope of Mauna Lòa three parallel hills or spurs, each about one mile in length, and from 800 to 1,800 feet in height. They include two broad valleys between them. The upper portions of these valleys rise with a steep incline towards a ridge which runs at right angles with the spurs, and is covered with a dense pulu forest, which extends far up the gentle slope of the dome of Mauna Lòa. In the second one of these valleys — that next to Mr. Lyman's — the so-called mud-flow took place, but very extensive land-slides, confined simply to the loose earth and conglomerate, also occurred in the other valleys.

"The ground around Reed and Richardson's station is torn up into numerous small cracks and fissures, running in every direction. Some are large enough to engulf horse and rider, a fact which actually occurred a few days after the earthquake. A large cistern, built in solid masonry and covered with an arched stone roof, was rent to pieces, and the roof entirely broken away. Not a single stone fence is standing; their places are indicated by flat belts of stone on the ground. The dwelling-house — a good wooden-framed one — exhibits a wrench across its roof, so that the gutters empty themselves in the sitting-room; the cook-house is thrown off its foundation; other out-buildings are completely overturned; and of the grass-houses, some are smashed down, others greatly inclined. But all these signs of destruction are thrown in the shade by the grandeur of the force which shook off

[1] On the side towards the sea.

the side of the pali, burying in a minute thirty-one human beings, many hundred head of cattle, and entire flocks of goats, and ending, four miles from its beginning, in a mighty river of mud. Before reaching this mud-flow from Reed's house, we passed two considerable streams of muddy water, of a reddish-yellow color, emitting a strong odor of clay, such as may be perceived in potteries. Both streams have their origin in the land-slide of the first valley. When we passed them again, two days later, they had nearly disappeared; they evidently owed their origin to the drainage of the fallen mass. The mud-flow is met with three miles from Reed's. It projects itself from the spurs of the hills two miles down in the plain; begins at once with a thickness of six feet, which, towards the middle, where it forms a small hill, rises to thirty feet; averages about three fourths of a mile in width, and contracts towards its end. From this end a long queue of boulders bears witness to the violent action of a torrent which shot out of the mud after it was deposited, and which has since perpetuated itself in a stream of some size, quite muddy, and emitting the above-mentioned pottery odor when we saw it first, on April 20th, but perfectly clear and inodorous when we passed it three days later. A little higher up a koa grove gives still stronger evidence of the strength of the propelling force. The trees first seized are snapped off and prostrate, yet the mud in that place is only a few feet deep. The mass itself is nothing but the loose red soil of the mountain-side, with a good sprinkling of round boulders, with here and there stumps of trees, ferns, *hapuu* and *amaumau*, and entire lehua trunks. Near the lower end a vigorous, healthy taro-plant stood erect in the mud, as if it had been planted there. From the sides of the mass protruded portions of the bodies of many cattle and goats, overwhelmed in their flight; a gain of one second in time might have saved them. The surface of the mud in this lower course was rather smooth, as if it had been forced down by the agency of water, and it was still so soft that the feet sank deep into it.

"After we had flanked it for some distance along the side of the hill, the mud became solid enough to bear our weight, and we walked upon it to the head of the pali. The surface gradually became more rough; the boulders increased, and detached portions of earth and stone were scattered beyond its borders, which also flattened out gradually. The ascent soon became steep, and here, on a short spur, just in the middle of the mud, stands a native house on an island of grass and kalo, flanked by two trees. A poor woman who happened to be in it at the time of the outbreak, escaped the awful fate which doomed the remaining members of her family, and was removed from her perilous situation a few days after, when the crust had become solid enough to bear a man's weight.

"As we went on, the mass became more rough and hard, tree trunks and boulders increased, even angular rocks appeared, until at last the mud ceased entirely and gave place to a sea of huge rocks, all angular and exhibiting fresh fractures, large trunks of trees crushed between and under them, and streamlets of fresh clear water meandering between them. This continued for the last three hundred feet of rise, and ended in a perpendicular wall of solid rock, some twenty feet high, after having climbed which, we reposed under the refreshing shade of tall fern trees, for we had entered at once the great pulu forest. Seated on the trunk of a prostrate tree, we could survey the whole field of devastation we had just traversed. Immediately at our feet the rocky frame-work of the pali was torn up, and its contents turned topsy-turvy in dire confusion. The rocky wall we had just climbed, continued itself until it reached the sides of the two flanking hills. A perpendicular cut in the sides of the latter laid open some forty feet of red earth and conglomerate. On looking behind us we saw that the rock we were resting on was separated from the mountain by a deep crevasse, parallel to the wall, and only partly visible, as it extended under the dense trees. To our left, a clear, sparkling mountain stream leaped in a bounding cascade over the crag, and after losing its course amid the maze of rocks, gathered itself again, flowing over the solid bed-rock in a deep gorge cut in the mud. This stream had existed here before, but ere it reached half down the pali, became lost in the soil. It can easily be imagined what an amount of subsoil water must have been deposited here. Bearing this in mind, and the great depth of soil and conglomerate on this slope, as indicated by the cuts in the hill-sides, there seems to be no great difficulty in explaining how such enormous masses of earth, at first propelled horizontally through the air, hurled down the valley by the tremendous force which tore off the side of the mountain, should then have been seized by the propelling force of the now liberated subsoil water, and carried in a mighty stream far beyond the place where at first they were deposited.

"On returning, we concluded to reach and follow the ridge of the hill flanking the stream on our left. Having arrived there, we could survey the extent of the land-slides on the opposite side of the hill, which were considerable. From this place, our guide pointed out to us a human figure in the distance, moving slowly over the dreary field. It was a husband searching for the body of his wife. Our guide, himself, poor fellow, mourned the loss of a wife, two little boys, and both parents. All slept their long sleep under that field of desolation. Following the crest of the hill still covered with grass and wood, we were startled by the number of fissures and crevices intersecting it in every direction. In some places, one was tempted to say that more space was occupied by them than by the solid crust.

"The direction of the solid rock wall and the crevasse in the forest, is northeast by north to southwest by south, nearly parallel to a line connecting Kilauéa with the lava outbreak in Kahúku. The stream running from the mud-flow is likely to remain permanent, as it is a continuance of the mountain stream above, and now runs upon exposed solid bed-rock.

"All this destruction was the work of the great earthquake of April 2d. During the five days preceding it, over one thousand shocks had been counted. On that afternoon Mr. Harbottle, at Reed's, with his men, was driving cattle across the hill towards Hìlo, when suddenly the earth shook violently and a great detonation was heard behind them. Horses and cattle turned round involuntarily. The whole atmosphere before them was red and black. In a very short time this subsided — some say in one minute, others in five minutes; but a black cloud continued to hover over the scene for some time. A native who resided less than half a mile from the scene, and who had friends living on the hill, found courage enough to run to it half an hour after the occurrence. He thrust his hand in the mud, and found it cold.

"From that Thursday to Sunday the earth constantly rocked and swayed; the hills seemed to alternately approach and recede. Most people became seasick. Strange roaring and surging noises were heard under the ground. When the ear was applied to the earth it would often receive a distinct impression as if a subterranean wave struck against the earth's crust. The prevailing direction of the earthquake waves was said to have been from northeast to southwest.

"During the twenty-four hours of April 21st, we experienced twenty shocks at Kápapala. From the upper road from Kápapala to Waiohínu (the lower road has been rendered impassable by the encroachments of the sea), several minor land-slides were observed on the hills; most houses were injured more or less; no stone wall remained anywhere. All the people from near the beach had taken refuge on higher lands near the upper road. My professional services were called for by many people who had been injured by the great oceanic earthquake waves. The great wave rose to a height of twenty-five feet, and according to reliable information, portions of the coast-line have subsided considerably. In some places coco-nut trees formerly out of water are now a foot deep in the sea. Every village along the coast of Ka-ù and part of Púna has been swept away. The whole population of Waiohínu I found encamped on a high hill to the east among the ferns. From two to three hundred people had lived there for two weeks under the scanty shelter of huts made of mats, fern and ki-leaves, and could not find it in their hearts to return to their houses and fields. Their crops, which before had already suffered from long-continued drought, were being invaded by the cattle, no fences remaining to protect them. It is much to be feared that the calamity of a famine will visit the smitten district in addition to the disasters suffered already.

"Of the damage done to the village of Waiohínu, other witnesses have given ample information. The hill forming the west side of the amphitheatre on which the village is located, has experienced a considerable land-slide. Less than five minutes' walk from Waiohínu a crack of eight feet in width has dislocated the Kóna road to the extent of its width. This fissure has a direction nearly south to north, tending towards the summit of Mauna Lòa. It is filled up with stones disgorged from it during the movement; the dislocation seems to be owing to a folding or kinking of the land on one side, for the fissure does not extend very far in either direction."

We now come to Kahúku. (See map on page 583.)

"Here the lava burst forth, April 7th, through an enormous fissure of nearly three miles in length, and ran in a few hours over a distance of twelve miles, from a height of 3,800 feet, — the highest point of the fissure, — to the sea, in which it caused a projection of more than half a mile. The upper portion of the stream is continuous; in its middle course, where it runs over the flat land, dotted with small hills, around and below the site of Captain Brown's former residence, it divides itself into several branches which leave a number of islands between them, and either unite again in the great pahoehoe stream which ran down to the sea, or end abruptly, mostly as aa. On following the old Kóna road the traveller is obliged, first, to pass around the tail end of an aa stream, then to cross two aa streams, and at last the pahoehoe. From a prominent hill near Captain Brown's house the scene can be best surveyed. On the islands between the several streams, many cattle and horses found refuge, most of which were saved after the cessation of the flow. On one hill stands a house which contained three poor sick men. When they became aware of the approach of the lava they attempted to escape, but not having strength enough left, they returned to their house, expecting death. The lava, however, only surrounded them, and as there were some provisions and water in the house, they kept themselves alive until it cooled, and succor was afforded them. The eruption must have ceased either on Saturday or Sunday night, the 11th or 12th of April. The accounts do not agree. About the exact time of the outbreak also there is some obscurity. The great fissure having been formed, in all probability on April 2d, the final breaking through of the lava seems to have begun almost without noise. Captain Brown only became aware of it by the sight of fire approaching toward his house, after darkness had set in, and then he hardly had time to save himself and family, the lava rushing down the last gulch ten minutes after he and his family had crossed it. From Mr. Whitney, who approached the stream from the Kóna side, I learn that a goatherd assured him that he had been prevented from returning to Waiohínu as early as the morning of April 7th, by the lava flow.

"As the principal interest was the discovery of the main source of the stream, we at once went to that part of it, where, according to common report, the lava had issued. A very light, dark-brown, glistening pumice-stone lay scattered about long before the lava was seen. Near the flow it increased so much that the animals' feet sank deep into it at every step. We soon reached the ridge of a hill from which we surveyed the place where, according to our guide's account, the fountains of lava had been seen. This upper portion of the lava stream fills a broad valley or depression, between two parallel low hills of not more than three hundred feet high, both running almost due north and south. From the western one of these hills Mr. Whitney had witnessed the eruption. From the eastern hill we in vain looked for a crater or cone. We did not make out any indication of an eruption until we had crossed nearly three fourths of the stream, which here is not far from a mile wide. Then our attention was attracted by an accumulation of scoriæ. Nearing this we were struck by a current of hot air, and, a little further on, found ourselves on the brink of a deep gap in the lava about twenty feet wide, but narrowing and continuing itself northward. We walked round the southern end of the gap, and followed it up on the western or lee side. Before long we came to another enlargement of the fissure like the former, emitting hot air charged with acid gases which drove us back. Still continuing our march on the west side of the fissure as close as the hot gases would allow, we came in sight of a pretty miniature cone, built up most regularly of loose scoria to the height of twelve feet, and located right over the fissure. It incloses a chimney crater of about twelve feet diameter, with perpendicular sides, the depth of which could not be ascertained. Hot gases issued in abundance. On account of the exhalation of the latter we were obliged to cross the chasm, on the bridge formed by the side of the cone, to the windward side, along which we followed up steadily.

"This crack or fissure tends south six degrees west to north six degrees east, and is in the slope of the hill that forms the west boundary of the lava stream. Its lava cover therefore is quite thin in many places, so that you can see how it sinks in the original rock of the hill. Its depth cannot be ascertained anywhere. More than four fifths of the lava is on its eastern side, as it followed the declivity of the hill-slope to fill the trough of the valley, where it assumed a general downward course. It is from the entire length of this fissure that the lava has welled up simultaneously. The waves of lava for some distance from it are all parallel to its course, while in the middle of the stream they stand at a right angle to it. The edges are somewhat raised above the remainder of the stream, and scoria covers it in most parts, forming quite heavy layers where the stream has blow-holes. Isolated flakes of brittle lava, resembling cow-dung, probably blown out at the end of the eruption, with fitful spouting of steam and gas, are seen all along its course. Nearing the upper end of the valley, where I expected to find the end of the fissure, I was surprised at the sudden appearance of a veritable cataract of lava coming down the precipitous side of the eastern hill, a height of at least three hundred feet. Having ascended it with considerable toil, I found myself again alongside the big crevasse, which in passing across the valley had deflected from its former course to a nearly N. E. direction, heading direct for the summit of Mauna Lòa.

"From here onward, the incline increasing considerably, the lava commenced to be very rugged and broken. As here it had passed over and destroyed a dense forest, a number of grotesque shapes met the eye. Wherever the lava had met a tree of some size, it had surrounded it with a perfect mould which either still held the smouldering remains of the trunk or exhibited hollow cylinders bearing on the inside the markings of the bark of the tree. The leaf stalk scars of fern-trees were almost perfect. A few of the moulds contained still, entire trunks with the unconsumed branches. In the bifurcations of these, heavy masses of lava had accumulated, hanging down in wavy points like so many stalactites. Wherever there was a fern stump standing upright, it bore a cap of lava; everything indicated that the liquid mass had been thrown upwards by the violent rush of steam and gas. As I said before, this part of the flow was lined by a dense forest. It soon became apparent that the sides of the forest closed in upon each other, and from an eminence alongside the fissure I could see that the lava stream contracted at some distance beyond to the apex of an isosceles triangle. The crevasse, which ran straight up to the apex, was continuous, wider than below, and emitted in great profusion sulphurous and other acid gases. Its borders, which were of the color of red brick, commenced to be covered with the efflorescence of salts and sulphur, and in places they assumed altogether the appearance of sulphur banks. The heat of the lava increased so as to be unbearable in some places. Ashes and scoria covered every hollow in the floor, and the edge of the woods for some distance.

"Having arrived at the apex of the triangle, I found that the crevasse, over which the trees almost closed from both sides, still extended a few hundred yards higher up in the woods, as indicated by a continuous line of white and yellow smoke. The choking nature of the latter forbade my marching along the edge of the fissure, while the impenetrable thicket, with the ground thickly covered by ashes, proved another effectual bar to my further progress. In fact, while hurrying out of an overpowering cloud of the smoke, I got one leg caught in a lateral fissure hidden under the ashes, where it received such a lively impression of heat that I made quick time to retire from that neighborhood. Just then I heard a deep, hollow, rumbling, prolonged sound, while the air and earth remained perfectly still. Subsequently I learned that it had been caused by the rolling down of large masses of pumice-stone from the hill to the lower lava stream, but at the time being fearful of another catastrophe, I hurried back as fast as circumstances would permit, and felt a great relief in rejoining my friends who had remained behind, at the lower part of the stream. From the height above the cataract I saw two other lines of smoke running through the woods, taking their origin from the lava valley below, indicating two other fissures. Thus it appears that at the head of the valley the main fissure divided itself into three parts: the first, and largest, running northeast; the middle one almost due north, and the third about north-northwest. The two latter did not seem to have thrown off much lava, if any, for there appeared no gap in the woods along their courses.

"HONOLULU, *May* 4, 1868."

From a letter addressed to me under date of August 27th, 1868, by the Rev. T. Coan, a correspondent of this society, I extract the following important facts, and accurate descriptions: —

"I left Hìlo on the 4th of August, on a missionary tour through Púna and Ka-ù, and was absent eighteen days. During this tour I made careful observations with measurements and notes, on the remarkable volcanic phenomena of the past five months. The action of tellurial forces upon our little island shell has been marvellous. The subsidence along the coast of Púna, from the east cape at Kapóho to Apùa, on the western line, is four to seven feet, varying in different localities. The great sand-beach at Kaimù has been forced back into the young and beautiful coco-palm grove, and also into the groves of pandanus, so that trees now stand eight feet deep in sand, and many stand in the water. The plain of Kalapàna (see fig. 27 on page 373) has sunk about six feet, and water four to five feet deep now covers some twenty acres of what was once dry land. The old stone church is buried nearly to the eaves in sand, and the tide rises and falls within it."

This plain of Kalapàna was doubtless at some former time buried much deeper beneath the sea. A coral reef of several yards thickness stretches half across the mouth of the valley, and formed a barrier against further encroachments of the sea. It was three or four feet above high-water mark, and formed a convenient site for the village. The church that Mr. Coan mentions was on this coral mound towards the shore. As the wall of rock which bounds the plain on the southerly side shows plainly that some former subsidence was caused by a rupture of the crust forming the floor of the plain from this wall, it would have been well to note any change at this point. Mr. Coan observed none, and the loose rocks knocked down by the protracted earthquakes would perhaps obliterate any traces of so slight a dislocation as a fall of six feet would cause.

"At Kealakómo the salt-works are destroyed, and the fountain on the shore sunk. Apùa, the last village in Púna, was swept clear [by the tidal wave of April 2d], and sunk. Its pretty sand-beach and miniature bay, rendering it a resort for fishermen, are no more; the sea stands some six feet deep where the houses once stood. The same is true of Keauhóu, the first village in Ka-ù, and an important pulu station; coco-nut trees stand seven feet deep in the water, and all the buildings were swept away by the tidal wave. Passing on to Punalúu, this wave rose twenty feet, and swept all before it. The great sand barrier which protected the beautiful pond and the cold, limpid spring, was first swept into the sea, and then brought back and deposited in the pond, filling it up, and changing the shore-line. I got the height of this wave by measurement on a palm-tree, and also upon the surrounding ridge of scoriform lava, making the rise above common high-water about twenty feet.

"From Punalúu onward to Honuápo, all houses were swept away except two standing on high lava ridges. The road was strown with boulders and fragments of rocks, and in some places it has sunk, so that it is with great difficulty, and not without a guide, that the traveller threads his zigzag way along this coast for five miles. Not a house remains in the considerable village of Honuápo; the sea occupies the site of former dwellings. The wave here corresponded to that at Punalúu, as shown by measurements on coco-nut trees. There were points where the influx of the sea was greater than at other places, and this seems to have been caused by the approach of the wave from the southwest, or at an angle of 45° to the shore, and by striking headlands and projecting points causing the waters to heap up within the points of tangency, while the current swept on at a lower mark where the coast presented no lateral obstructions. The foregoing remarks will apply to the whole coast from Kapóho to Kalàe, the southern cape.

"In crossing over the great lava-fields from Púna to Ka-ù, I passed about nine miles to the south and leeward of Kilauéa, the great volcano flanking us on the right. The country through which we passed was terribly rent by the earthquake of April 2d, and in some places we were obliged to deflect widely from the old track to avoid fissures. For several miles the cracks were so numerous and so wide, that a stranger would be utterly unable to find his way through the meshes of this mural net-work of fractures. Our guide zigzaged us everywhere, our animals often demurring, trembling, and refusing to go. The whole atmosphere was filled with sulphurous smoke, through which the sun shone with sanguine rays. After passing most of these fissures, I requested my guide to turn to the left and follow the line of fissure seaward, hoping to find the locality of a disputed eruption which it was affirmed by some and denied by others had taken place in that wide and wild field of ancient lavas. After an hour of hard search amidst hills and ridges of aa and fields of pahoehoe, we found a veritable eruption. The fused lavas had been thrown out of the fissures at five different points, on a line of less than a mile in length. The largest patch was one thousand feet long and six hundred feet wide, with an average depth of ten feet, and with a steaming and tumulated surface. This series of small eruptions is about eleven miles southwest of Kilauéa, and it shows distinctly the subterranean path taken by the igneous flood which left that seething cauldron on the night after the rending earthquake of April 2d. That shock doubtless opened a pathway for the struggling fires, and they went off in a southwestern course under the highlands of Ka-ù, uniting with the subterranean fires of Mauna Lòa, and finding a fuller vent at Kahúku on the seventh of April. This is the theory, and it is rendered probable by the great and constant trembling of the earth along that whole line, by subterranean noises heard by the people of Kápapala, Keàiwa, Waiohínu, and other places, and by the issuing of steam at several points from fissures along that line."

When it was found that Kilauéa had discharged its contents, the first supposition was that the course of the eruption of 1840, or towards the southeast, had been followed, and this was strengthened by the report of fire seen at the bottom of some of the numerous pit craters on that line; but while it is possible that lava may have been injected in earthquake fissures opened in this direction even so far as the pit craters described on page 429, the probable path was that indicated by Mr. Coan, which is apparently the same as that of the eruption of 1823. When Rev. William Ellis went over the ground the next year he found deep fissures extending in a southwest direction, some of them ten or twelve feet across, and emitting sulphureous vapors at a high temperature.[1] In one place, where the chasm was about three feet wide, a large quantity of lava had been recently vomited.[2] A native assured him that the lava had first been noticed three weeks before his visit. I do not agree with Mr. Coan in supposing that the lava from Kilauéa and that from Mauna Lòa effected a juncture before reaching the surface. It seems more probable that the former passed into the sea near Punalúu, as did that of 1823, not appearing above ground except at Kápapala. The fact that the openings on the side of Mauna Lòa above Kahúku were much higher than those mentioned at Kápapala, seems to indicate conclusively that the lava of Kilauéa did not flow out in the stream that deluged the height above Kalàe. The lava of both of these volcanic vents is so similar that nothing can be inferred of its individual source. The ancient, commingled flows of lava which cover the ground for some ten or fifteen miles south and west of Kilauéa, came, some from that crater by vents similar to that near Kápapala, and others from Mauna Lòa, and they are so identical in substance and appearance, that their position alone distinguishes them.

[1] *Ellis's Polynesian Researches*, Vol. IV, p. 220, *et seq.* London, 1859.

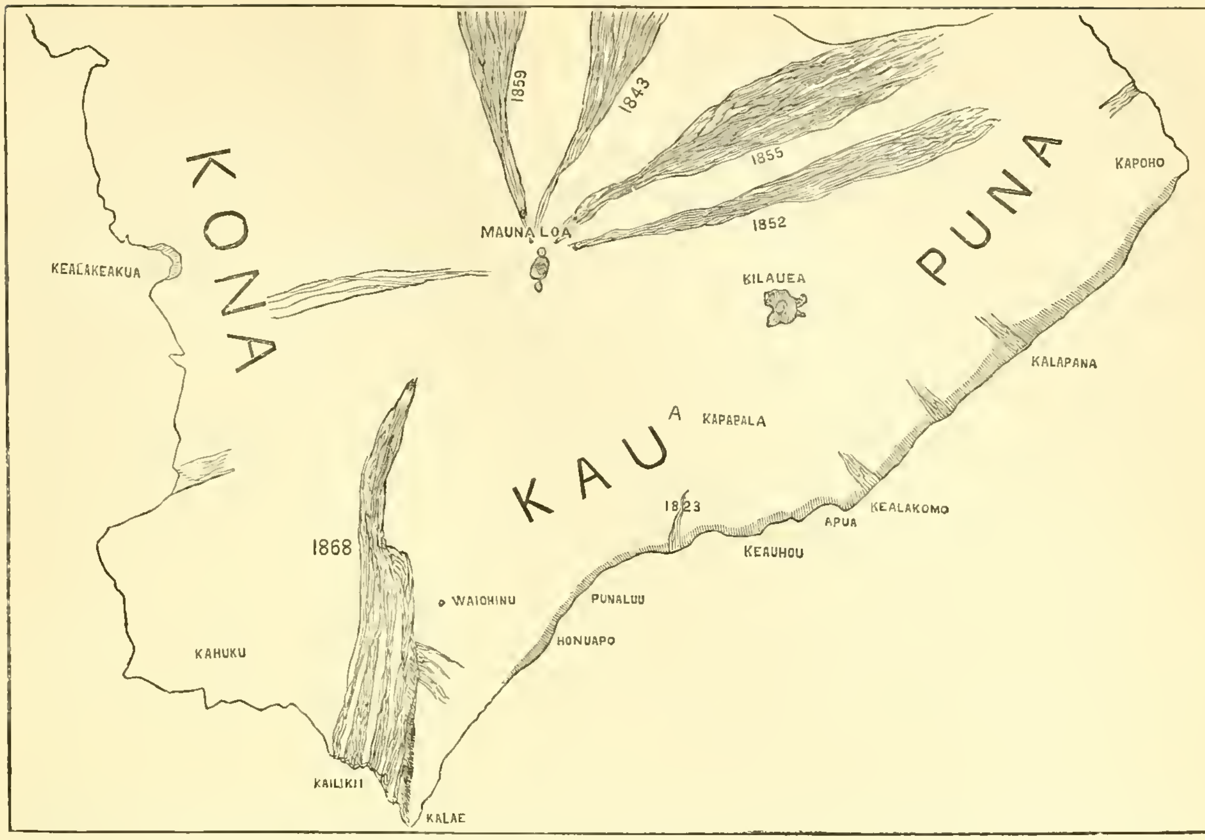
[2] See plate in *A Tour through Hawaii*, by Rev. William Ellis. London. 1827, p. 203.

Land-slide. "Between Kápapala and Keàiwa in Ka-ù, I examined what has incorrectly been called the 'Mud Flow.' I went entirely around it, and crossed it at its head and centre, measuring its length and breadth, which I found were severally three miles long and half a mile wide. The breadth at the head is about a mile, and the ground on the side hill, where the cleavage took place, is now a bold precipice sixty feet high. Below this line of fracture the superstrata of the earth, consisting of soil, rocks, lavas, boulders, trees, roots, ferns, and all tropical jungle, and water, slid and rolled down an incline of some 20°, until the immense masses came to the brow of a precipice near a thousand feet high, and here all plunged down an incline of 40° to 70° to the cultivated and inhabited plains below. The momentum acquired by this terrific slide was so great that the mass was forced over the plain, and even up an angle of 1° 30′, at the rate of more than a mile a minute. In its course it swept along enormous trees, and rocks from the size of a pebble to those weighing many tons. Immense blocks of lava, some fresh as of yesterday, and others in all stages of decomposition, were uncovered by the slide. The depth of the deposit on the grass plains may average six feet; in depressions at the foot of the precipice it may be thirty or even forty feet.

"I had heard that this was a 'mud eruption,' and had supposed that the explosive force of steam or gases had riven the precipice and projected this immense mass over the plains; but on personal examination I am sure that it is nothing more than a land-slide or avalanche of earth and rocks shaken off from the steep hill-side and propelled by its own gravity. This is evident from the fact that there was no heat, steam, nor smoke connected with the slide, except the *dust* which would naturally arise by the motion of so vast a body of earth.

Eruption in Kahúku. "From the land-slide I went on to the igneous eruption in western Ka-ù. Rents, tiltings, and other disturbances of the strata were seen along the shore, while the wooded and grassy hills on the right were scalped, scarred, cracked, and striated; some of the once green hills looked as if a gigantic cultivator had been driven down their sides, tearing off the sward and exposing the soil in wide parallel grooves, and leaving broad belts of vegetation resembling rows of sugar-cane. In passing from Waiohínu to Kahúku, we started a little after sunrise, and rode westward. About three miles from Waiohínu we crossed a lateral arm of the eruption, about one sixteenth of a mile wide and some two miles long, from where it left the parent stream. It was a high ridge of aa, say twenty-five feet deep, and running in a southeasterly direction. Crossing this, and riding half a mile over verdant and beautiful fields, we came to another lateral outgush of similar character and dimensions. Then came a third, which flowed some four miles, and threatened to fill the harbor of Kaáluálu. This was longer and broader than the other two, but of the same general character. After another half mile we crossed a fourth rugged stream of aa, and then moving southwest we rode rapidly over a fine surface of soil down a slope of about 3° to the ends of the two large parallel streams that entered the sea at Kailikìi. Over all this wide field of pasturage, cinder and pumice had been scattered, and the grass had been consumed as by a prairie fire.

This portion of the eruption went into the sea about one mile northwest of Kalàe, the south cape of the island. On the left flank of the streams is a high and very steep ridge (four hundred to five hundred feet high) extending from the cape up the southern slope



Map of Southern Hawaii and the Eruption of 1868.[1]

of Mauna Lòa. The outburst of April 7th commenced about ten miles from the sea by the opening of a horrid fissure in the forest on the upper side of this precipice. For about three miles the burning river flowed down partly above and partly below this precipice. The area above was rich and beautiful land for cultivation and pasturage ; that below was simply pahoehoe. The four lateral streams before mentioned all ran off upon the beautiful highlands, covering several thousand acres, but without reaching the sea. Some three miles from the head, the main stream went altogether over the precipice, and pursued its rapid course over the pahoehoe some seven miles to the sea, which it reached in two hours. There it formed, as is usual when lava streams enter the sea, two cones of lava sand, or lava shivered into millions of particles by coming in contact with water while in an intensely heated state. There is no island there, and there is nothing but what is common under similar circumstances. This stream is about half a mile wide, and it entered the sea some three fourths of a mile from the high pali before spoken of. After running a day or two, in this channel, partial obstructions occurred, by cooling masses, when the shell of the stream was tapped some five miles from the sea, and a torrent of white-hot lava pushed out on the east side, running off to the great precipice and following its base in a breadth of half a mile down to the sea, and thus forming an island five miles long and a quarter of a mile wide, surrounded on three sides by fire. Three houses stand unscathed on this islet, and about thirty head of cattle were inclosed by the igneous flood."

[1] The lava streams are greatly exaggerated in breadth, and show merely the general form.

The route taken by this lava flow was substantially that of a stream of unknown date, but whose smooth surface of hard pahoehoe looks fresh and undecomposed. Where this ancient stream originated is not known, for no one has ever taken the trouble to trace up the various flows which radiate like the spokes of a wheel from the cone of Mauna Lòa. The pali referred to was evidently formed by the subsidence of the ground over which the successive streams of lava have flowed, and it forms the boundary of a fine pasture land, which appears to have been exempt from these lava inundations for many ages; the outcropping ledges of lava are weathered and lichen covered until they much resemble the gneiss and granite rocks of New England, at least from a distance.

The flow of 1840, which reached the sea at Nanawálie, formed conical hills which have not wholly been washed away to this day, although composed of the loose gravelly rapilli resulting from the sudden shivering of the lava, and the same form of cinder piles is seen in the junction of lava and sea-water in this flow of 1868. It is not universally the case, however, that lava is broken up in this way on pouring into the sea. Sometimes the heat has been too intense to permit the actual contact of the water, and the melted rock has run on under the sea, forming submarine ledges of pahoehoe.

"From the shore we rode up on the elevated plateau with the two parallel streams of cooled lava on our left, some five hundred feet below, with nothing to obstruct a full bird's-eye view of the scene. At length we came to the great trunk at Kahúku, from which all the lateral branches had been sent off. At our right on one of these branches were the ruins of the large stone church of Kahúku. The great earthquake had shaken down the walls, and the roof was lowered and standing over the ruins, around which the sea of molten lava had flowed, leaving them upon a small island unconsumed and uncovered. One eighth of a mile above this, and on the same stream, we saw three small thatched houses where four natives had been surrounded by the burning sea and confined for ten days in this fiery prison. The whole inclosed island contained about an acre, and before the people were aware of it, no avenue of escape was left. The hot clinkers came rolling along in a great stream within twenty-five feet of one of the houses, and cooled in a ridge as high as the top of the house. We climbed over this rough mass and visited the people who still live in this once awful but now romantic inclosure. They seemed cheerful, and were right glad to see us. On inquiring how they felt and how they spent their time during those days of fiery trial, they replied that in expectation of certain death they were calm and resigned, looking up to God and spending most of their time in prayer.

"Passing up the main stream, we came to the place where Captain Brown's houses once stood; just in the rear of this was an awful vent from which fiery jets were thrown hundreds of feet high, with fearful hissings and belchings. Beyond this we saw numbers of green islets, of two to five acres in extent, formed by the surging sea of fire as it seethed and boiled and swept around these reserved places. On some of these islands cattle were feeding, and twenty head were taken from one islet of less than two acres, after the lavas were partly cooled. They were terribly heated and frantic, and some of them died. Still pursuing our course upward, we veered to the right, and once more took the soil on the uplands which bordered the stream. Here the great trunk of the stream was in its full breadth, and here I hired two men to measure across, while we rode through a charred forest and deep cinders more than one hundred feet above the shining lava-fields which lay on our left. At length we descended again to the stream of fresh and warm pahoehoe, and rode nearly a mile upon its crackling surface. We soon came to a region of fissures and blow-holes, and where the evidences of Plutonic fury were unmistakable. From these infernal orifices amazing jets had been thrown hundreds of feet heavenwards, forming ridges, hills, and jagged cones of every contour, and leaving the products of raging seas and rivers of fire, such as must have been appalling to a near witness of these fiery dynamics. Here we left our horses, and with great effort struggled over the sharp and confused masses which were heaped wildly around. Climbing a rough hill-side some two hundred feet high, and on an angle of 45°, we came upon the great head fissure from which the first lavas were disgorged. We followed this to its terminal point in the woods, over ridges and heaps of cinder, pumice [limu], and scoria. From this high terrace we could overlook the stream below for about three miles. The great vent or fissure extended longitudinally and in an irregular line for two and a half miles or more, and at many points along this line steam and smoke were still rising with no little heat. No fire was, however, seen; it all disappeared in less than four days after the commencement of the eruption. The fissure opened from two to twenty feet wide, and there are places, where it is interrupted, or so narrow that it can be crossed.

"Near the head of this fissure a small quantity of sulphur is found, as also alum, gypsum, Glauber's and other salts; none of these are abundant, and the products of this eruption are identical with those of all former eruptions on this island. Returning to the point whence I had sent men to line across the stream, I regretted to find that they had measured until they came to the great fissure, and seeing no way of crossing it, had returned. They had measured half a mile, and thought they were half-way across, but from sight I judged they were only one third across, giving a mile and a half as the estimated width at this point, which was about the widest place of the undivided or trunk stream. I would say that the average width of the flow by uniting all the branches would be one and a half miles, the length ten miles, and the average depth fifteen feet. Where it entered deep basins and gorges it is fifty to a hundred feet deep, but where it spread over grass fields and unbroken surfaces, we find it from two to fifteen feet deep. The course of the main stream, the one that entered the sea, is due south. The flow upon the surface was short and energetic, some say three and some five days, — we give it as four days. The scene was brilliant and awe-inspiring; obstructions along the line of flow often opened vents through which fiery jets were thrown up to the height of five hundred to seven hundred feet, with amazing brilliancy and a force which made the earth tremble. All the southern coast of Hawaii was illuminated with the dazzling glare: but the amount of matter discharged is small compared with the eruption of 1855.

"Having spent the whole day in laborious examination of the lava streams, we returned to Waiohínu after sunset. This eruption is of easy access; one can ride on its eastern margin all the way from its entrance into the sea to within a quarter of a mile of the points of outbreak at the head, and the four lateral arms can be examined at leisure as they lie like so many black serpents upon the open grazing land and cultivated fields."

Kilauéa. "In going to Ka-ŭ my route was along the shore road through Púna; my return was via Kilauéa. At this place I spent a day and a night, and examined the changes. Previous to the great earthquake, the fiery abysses of Kilauéa had been in a raging condition, as if seeking vent. The molten sea had broken up vertically in the bottom of Little Kilauéa

[Poli-o-Keàwe of the Map, Pl. XV.], and left a burning stratum upon the old deposits of 1832. The terrible rendings of April 2d tore up the earth, opened great fissures everywhere around Kilauéa, sent down thundering avalanches of rocks from the high surrounding walls, and probably opened a subterranean passage for the igneous flood to the southwest. That night Pélé decamped in this underground passage, and the central area of the great crater subsided about three hundred feet, leaving or rather forming a new 'Black Ledge' of unequal width, all around the crater. In some parts the central depression left the ledge a perpendicular or beetling wall with a serrated line, but in most parts the centre sagged away gently, forming a large concave basin with an angle of 20° to 70°. The surface of this concave was once the crowning or convex central portion of the crater, where ferns and ohelo bushes have been growing for nearly twenty years. This superincumbent plateau has been depressed so quietly that the surface is very little disturbed, and the ferns and bushes are still growing in the basin three hundred feet below their position on the first of April. Some parts, however, of this great area have been covered with fresh lava, and some ferns have been killed by heat and gases.

"From the Black Ledge I passed down and across this depression (about a mile), and then up the ascent on the other side for half a mile to the rim of Halemáumau. This is all changed: it has gone down some five hundred feet below the highest point on the Black Ledge, and about two hundred feet below the depression in the basin before mentioned. The walls have fallen on all sides, and the pit resembles a vast funnel, half a mile in diameter at the top and about fifteen hundred feet across the bottom. There are two places where visitors can descend into this great pit, with some difficulty and risk. Much of the time, this pit is filled with smoke and sulphurous gases, with little visible fire; occasionally, however, explosions, detonations, and fiery demonstrations occur in this awful pit.

"Our earthquakes still continue. Taking all parts of the island, they now average two to three a day; most of them are light. We have now had five months of constant disturbance; what will follow, is known only to 'Him in whose hand our breath is,' and who rolls the wheels of universal nature.

"On the 14th, 15th, and 16th of this month (August), the sea was agitated around our entire group, rising and falling from two to four feet above and below the ordinary marks, once in ten, fifteen, and twenty-five minutes; the accounts of rise and time vary as noted in different places by different observers, and I give the range. Not much damage was done. A bridge over our Waiakéa river was lifted and carried up stream a third of a mile to the royal mullet pond; dams were broken, and some boats set adrift and injured. The influx of the sea on the 2d of April is accounted for by the terrible earthquakes, but the late oscillations were not attended by any unusual disturbances on land. Were these rapid and long-continued pulsations occasioned by submarine eruptions of our own or neighboring volcanoes?"

The sea-waves of which Mr. Coan speaks were doubtless caused by the terrible earthquake which on the 13th of August shook the whole western coast of South America, and drove an oceanic wave to the shores of New Zealand and these islands. But although this was decidedly a foreign volcanic or seismic demonstration, the vibrations of the land of Hawaii have not ceased, and it is not at all improbable that the reservoirs of lava are emptying themselves beneath the sea: certainly the lava is in motion, and I am strongly inclined to the belief that all these shocks and tremors are due to the effect of heat passing from incandescent lavas to the cold or moist strata superincumbent or adjacent. In that case, the hot lavas entering a crevice between cold or moist rocks would originate a series of vibrations which would break open the rock more and more and expose fresh surfaces to the hot lava; and so on until the heat of the lava has been reduced by conduction to a certain point, when the vibrations cease. If the theory be true that all volcanic eruptions are but the passage of telluric heat into space (our earth's crust being a good non-conductor and compelling the passage by certain open ways which are marked by volcanoes), and if this escaping caloric, sometimes compelled to seek one avenue of escape, sometimes another, but when escaping reducing to liquidity all the material of the crust in its way, forming what we call lava lakes as in Kilauéa, or when less equable, or when, as it were, blocked up or opposed, driving all before it as an eruption or flow of lava, — if this theory be true — and experiments are now being made to throw light upon it — it is not strange that this heat passing through the crust near volcanic vents should act as above supposed.

The destruction of life and property on Hawaii was comparatively small, owing to the nature of the district affected. The losses were as follows: —

Number of houses destroyed by land-slide	10	Deaths	31	In Ka-ù.
Number of houses destroyed by sea-wave	108	Deaths	46	
Number of houses destroyed by earthquake	46	Deaths	0	
Number of houses destroyed by lava-stream	37	Deaths	0	
Total	201		77	

One life was lost in Púna by the sea-wave, and one in Hílo by a falling cliff. A shock of no greater violence in the city of Boston would probably have killed fifty thousand people, and laid most of the city in ruins.

The data for determining the direction and force of the vibrations, are quite different from those used by Mallet in his remarkable investigation of the Calabrian earthquake of 1857. The houses are mostly of wood and grass, and stone walls are built of angular blocks of lava, often without any cement; a brick wall or a wall of hewn stone, is not to be found in Ka-ù. On the other hand, the rocks which form the upper crest are of uniform composition, the direction of the strata is well known, and there are no strata of sedimentary rock to mislead by reflection of earth-waves. On the whole, Hawaii offers many advantages for the study of seismic as well as volcanic phenomena.

Published March, 1869.

XVIII. *The Physical Geology of Eastern Ohio.* By Colonel Charles Whittlesey.

Read February 3, 1869.

WHILE engaged upon the Geological Survey of Ohio, under the late Professor W. W. Mather, thirty years since, my duties were principally confined to the physical side of geology. The survey was abruptly terminated in the spring of 1839, before a reconnoissance of the State had been completed. No final report was made or called for. Two brief preliminary reports, which are now rare, were published in pamphlet form. It was a part of Professor Mather's plan, to determine not only the boundaries of the formations in a geological sense, but to ascertain their exact dip, thickness, and mass, by topographical surveys and levels. This part of the work was confided to me, constituting a department which has never been thoroughly carried out in any of the State surveys. Our intention was to construct for each county a correct map, with geological profiles which should be mathematically exact.

The profiles would thus show all the irregularities in the thickness and dip of the strata in the coal region, which embraces about one third of the State on the east. This is of the highest practical importance, because the coal seams, and all the other beds of the coal series, thin out, thicken up, or disappear, in short distances. They are not at all regular, like the English series. Such detailed maps would have constituted a State Geological Atlas, based upon actual surveys.

Most of the information collected by me for this purpose was left in the office at Columbus, and is now lost. My field-books were retained, and probably the other members of the survey retained theirs; but Professor Mather, Professor Locke, and Mr. Hildreth are dead. Of the field geologists, only Professor Briggs, Colonel Foster, and myself survive. Professor Kirtland's Report on the Natural History of the State was more complete than the others; his department therefore suffered less by the unexpected termination of the survey, than the departments of geology and mineralogy. In 1838, there had been surveys made along the principal valleys north and south, on routes from Lake Erie to the Ohio, to determine the feasibility of canals. The office of the Canal Commissioners, to whom the present "Board of Public Works" are successors, then contained all the levels taken for canal purposes. Since that time the State has been intersected by a great number of surveyed lines for railways, crossing the canal surveys at all angles. This net-work of surveys gives with reasonable accuracy the elevations of the principal summits, which I have preserved as far as practicable, in the hope that the geological survey might be renewed, and that in addition to correct profiles of the strata, there might be made an exact geological and topographical *model* of the State. The railway surveys are not anywhere collected in one office. Many of them are lost, or so dispersed among the papers of defunct corporations, that they are inaccessible. Of late years, I. N. Pillsbury, Esq., of Cleveland, a well-known civil engineer, has assisted me in collecting the profiles and surveys of railroads, and has recorded in book form the elevations of the prominent points. In comparing levels on different lines, we have found numerous discrepancies, in some cases amounting to (10) ten feet. They arise from three sources. First: inaccuracies such as occur in all preliminary lines, to which no subsequent corrections are applied. Second: in all surveys commencing at Lake Erie, the water line for the moment is made *zero*; and this is subject to a fluctuation of many feet. The mean elevation of the surface of this lake is not determined precisely. I have discussed this subject for all the lakes, in the Smithsonian Contributions for 1859, where the observations for fluctuation are presented from 1790 to 1854. The greatest known change of level is six feet eight inches (6 ft. 8 in.); the lowest stage having been reached in the winter of 1819, and the highest in June, 1838. A temporary rise in 1854 slightly exceeded that of 1838. Taking the water registers prior to 1854, which were so fully kept as to give a good monthly mean for a period of seven (7) years, the greatest mean monthly difference was four feet nine and a half inches (4 ft. $9\frac{1}{2}$ in.); and for a period of four years during which there was a full record, the greatest difference of years was four feet one and three fourths inches (4 ft. $1\frac{3}{4}$ in.). Daily observations are now going on for all the lakes, as a part of the government hydrographical surveys, which will require many years for completion. Until the mean fluctuations are determined more accurately, I use for the mean surface of Lake Erie, the average of four surveys, made from tide water, as shown in the following table.

Elevation of the Great Lakes above the Ocean.

To fix the elevation of the lakes, I begin at those nearest the sea, to which instrumental surveys have been made.

LAKE ONTARIO.	
By lockage in the St. Lawrence canals, above mean tide	$234\frac{1}{2}$ feet.
By canal surveys of New York, above mean tide	232 feet.
Mean	$233\frac{1}{4}$ feet.
LAKE ERIE.	
By canal surveys in New York, 1817	561.20 feet.
By Captain Williams' Report of 1834, Niagara Ship Canal	563.00 feet.
By surveys Caatskill and Portland Railway, 1828	565.33 feet.
By locks of New York Canal	567.00 feet.
Mean	564.13 feet.
LAKE HURON.	
S. W. Higgins' Geological Report of Michigan, 1838	577 feet.
A. Murray, Geological Report of Canada, 1849	578 feet.
Mean	$577\frac{1}{2}$ feet.
Lake St. Clair, Geological Report, Michigan	570 feet.
LAKE MICHIGAN.	
Southern Michigan Railway, J. H. Sargent, Engineer, survey of 1856, south end	583 feet.
LAKE SUPERIOR.	
By Captain Bayfield's barometrical measurement in 1824, 627 feet, evidently too great.	
A. Murray's determination, Geological Survey of Canada, 1849, 599.41 feet, say	600 feet.
Survey of Bay D'Enoch & Marquette Railroad, 1859	610 feet.
Mean	605 feet.

There is in all these lakes a slight current towards the outlets, and therefore their surfaces are not strictly level; which accounts for some of the discrepancies in their reported elevations. At Cleveland, the high water mark of June, 1838, is well preserved, having been adopted by Mr. Pillsbury as the *city directrix*, or the zero for city surveys. Assuming the mean elevation of Lake Erie at 564.13 feet, as given above, the directrix should not vary more than half a foot from five hundred and sixty-six and a half ($566\frac{1}{2}$) feet above tide. The elevations below given, refer to this mean water line, unless the city zero is mentioned; which mean level is considered as five hundred and sixty-four (564) feet. Fractions of feet will generally be omitted. A third source of error arises from the uncertainty of the zero, or starting point, of some of the interior surveys. This does not exceed the other errors incident to disconnected surveys, made by different persons, at different times, under no official or State supervision. We think the greatest correction cannot exceed plus and minus five; so that the greatest error will not exceed ten feet, and in nearly all cases will be within three feet. A large part of the figures are correct within half a foot.

Triangulations for Dip in the Coal Series.

In Ohio, the coal-bearing rocks are the most recent of the indurated strata, forming a large segment of the great Appalachian coal field. The only newer beds in the State are the Quaternary, or drift, which everywhere cover the indurated rocks. On my geological maps of 1856 and 1869, the coal region occupies about one third of the State, on the east and southeast. From the curved lines of outcrop, where the conglomerate comes up on the north, northwest, and west, the dip of the coal strata is in the opposite direction, south and southeasterly, as the following calculations will show. These and all the Ohio rocks are so nearly level, that the inclination is not in general perceptible to the eye, except in cases of local undulations. Around the base of the coal, the succeeding formations are generally conformable, over a wide field, to the north and west; but in the southwestern part of the State is a low crown or flat dome, where the silurian strata dip in all directions.

Tallmadge, Briar Hill, and Brookfield. — At the Northwest Six Corners, Tallmadge, Summit County, the lowest coal seam (Newberry's old entry) is 527 feet above Lake Erie; thence to Briar Hill (old entry), near Youngstown, Mahoning County, the course is east 41.2 miles, 342 feet above Lake Erie; thence north $33\frac{1}{2}°$ east, $11\frac{1}{2}$ miles, is Curtis' old entry, in Brookfield, on State Line, near Sharon, Pennsylvania, and nearly on the line of bearing. These points fix the direction of the dip, at south $12\frac{1}{2}°$ east; rate 20.6 feet per mile. "Coal Hill," Tallmadge, is an outlier of the coal series, $1\frac{1}{2}$ miles long, north and south, beneath which the coal is mostly worked out. From the north end, at the Northwest Six Corners, to the south end, the bed, which lies in the form of a local basin, sinks 28 feet. The mean of the lowest parts of the mines is 505 feet A, the sump of Newberry's old mine is 517 feet, and that of Briar Hill, 318 feet A. Two mines at the mouth of Newman's Creek, near Massillon, Stark County, the Union Company's sump (346 feet A), the Massillon Company's sump on the same level, combined with Tallmadge and Briar Hill, give for the dip of the bottom seam, south $53\frac{1}{2}°$ east, $8\frac{1}{3}$ feet per mile. At Massillon, and on Newman's Creek, the local basins have their outcropping edges from twenty to forty feet above the sumps of the mines. Some short lines in the lower seam, around Clinton, Summit County, between Massillon and Tallmadge, give for local dip, south $23\frac{1}{2}°$ east, 9.1 feet per mile, and in the valley of Newman's Creek, south 71° east, 15.6 feet per mile, disclosing local irregularities such as appear in all parts of the field. The general elevation of these mines will be found below. Around Bolivar, about twelve miles below Massillon, on the Tuscarawas, the lowest bed of limestone in the coal series, which is about 160 feet above the lowest coal seam, is well developed. By lines from three to five miles in length, in this bed of lime rock, the greatest inclination is found to be, south 72° east, 25.2 feet per mile. In the mining region on the Mahoning, around Youngstown, the elevation of most of the entries, and of some of the sumps, has been well taken. Here the bottom seam, commonly called the "Block Coal," frequently rests on the conglomerate, which is thin. From the Mount Nebo works, near Lowell, bottom of the mine 222 feet A, to Briar Hill shaft sump. 318 feet A, is, north 46½° east, 7.45 miles; to Ewing's coal, in a drill hole, 305 feet A north 85½° west, is 13 miles; and the result for dip is, south 22½° east, 14 feet per mile.

A triangle formed by Mount Nebo, Briar Hill, and the coal at Porter's furnace, lying between Ewing's and Briar Hill, gives, south 37° east, 13 feet per mile; and another, connecting Mount Nebo, Ewing's, and the sump at Rice, French, & Co.'s shaft, on Mineral Ridge 377 feet A, south 18° east, 16.6 feet per mile. In this region, as at Massillon, there are many irregularities in the coal seam, which lies in troughs and basins whose lowest parts are thirty to sixty feet below the outcrop. It requires lines of at least ten miles in length, where the beds are so flat and so much curved, to determine the general direction and amount of their inclination; but when thus obtained, it will be perceived the results agree very well with each other.

Elevations in the Lower Coal Seam.

In Ohio, the coal seams are not persistent, which is shown conclusively by profiles already made, in different parts of the field, extending from the margin to a common centre near Wheeling. It is therefore a fallacy to suppose that beds in different parts of the basin can be identified with those in others, either by their associated rocks, or a similarity in the external character of the coal. Where the number of seams in one profile is more or less than in another, there cannot be identity. A bottom seam will of course be everywhere found, from zero to eighty feet above the conglomerate, but it is not everywhere the same seam. It frequently thins out, and disappears, while another seam sets in, overlapping, or underlapping, as the case may be, having different physical characters and associations, but nearly in the same horizon. Above this, it is very difficult to connect the beds, over large spaces, either of coal, limestone, iron ore, or sandstone. It is very rarely that any bed of the coal series can be traced with certainty one hundred miles.

Beginning on the State line between Ohio and Pennsylvania, I now give what elevations I have procured for the bottom coal seam, or No. 1, proceeding in order, to the west and south around the border, where only as yet this bed has been well observed. In the deep borings, within the basin, it has frequently been found to be wanting; the lowest seam not being a continuation of No. 1. For convenience and brevity, I shall, however, designate the beds by numbers, having stated that one is not to be regarded as the geological equivalent of another, because the number is the same.

ELEVATION OF POINTS IN THE LOWER COAL SEAM.

Curtis' old entry (1838), Brookfield	426 feet.
Mineral Ridge (Ward's old bank), Weathersfield	369 feet.
Girard banks on Four-mile Run, lowest part	295 feet.
Briar Hill, bottom of sump shaft	318 feet.
Dr. Manning's old entry near Youngstown	332 feet.
Powers' bank, three miles below Youngstown	285 feet.
Mount Nebo, near Lowell, lowest part	222 feet.

Porter's furnace, Austintown, sump	332 feet.
Ewing's boring, Austintown, south line	305 feet.
Paris township, Portage County, northwest part	470 feet.
Charlestown, Portage County, one half mile west of centre	430 feet.
Edinburg, Portage County, on Barrel Run	440 feet.
Tallmadge, Summit County, Northwest Six Corners sump	517 feet.
Tallmadge, Summit County, Harris mine one half mile east outcrop	527 feet.
Tallmadge, Summit County Coal Company's old entry	498 feet.
Tallmadge, Summit County, Whittlesey's old entry	512 feet.
Tallmadge, Summit County, old entry, south end of coal hill	498 feet.
Springfield, Summit County, De Haven's old entry	487 feet.
Coventry, Summit County, A. Brewster's old entry	525 feet.
Chippeway, Wayne County, Wood's bank	480 feet.
Chippeway, Wayne County, Crawford's old entry, near Clinton	463 feet.
Lawrenceville, Wayne County, on Newman's Creek	416 feet.
Massillon, Stark County, Union Company outcrop	361 feet.
Massillon, Stark County, Massillon Coal Company, mouth of Newman's Creek, old entry	346 feet.
Massillon, Stark County, Union Company's sump	346 feet.
Massillon, Stark County, Kilpatrick & Co.'s old entry on canal	371 feet.
Massillon, Stark County, outcrop on Shelley's Run	393 feet.
Three miles north of Millersburg, Holmes County, about	360 feet.
Coshocton County, $1\frac{1}{2}$ miles west of Warsaw	348 feet.
Coshocton County, Newcastle, near west line of county, western outcrop	513 feet.
Muskingum County, near Brownsville, 37 miles east of Columbus	270 feet.
Four miles west of Brownsville, western outcrop, about	400 feet.
Outcrop on the Ohio River near the Little Scioto, about	200 feet.
Outcrop near Jackson County court-house, about	195 feet.

These figures extend over a space along or near the outcrop about four hundred miles in length. They show that the rim of the coal basin in Ohio is nearly level, as might be expected in a country where the summits of the hills lie in nearly a horizontal plane. The variation from such a plane seldom exceeds one hundred feet, as will appear from the following table, embracing water-crests and adjacent highlands in different parts of the State.

ELEVATION OF THE PRINCIPAL SUMMITS IN OHIO.

Summit of the Clear Fork of Mohican, Owl Creek, Olentangy, and Sandusky Rivers, southeast part of Richland County, highest land in the State	825 feet.
Summit between Clear Fork and Pine Run, north part of Knox County	714 feet.
Summit between Six-mile Run and Schenck's Run, north part of Knox County	720 feet.
Summit between Schenck's and Ball's Run	660 feet.
Summit between Jerome's Fork and Muddy Fork, of Mohican, northwest corner of Wayne Co.	700 feet.
Summit between Killbuck and Mohican, southwest part of Holmes County	585 feet.
Summit between Killbuck and Black River, Medina County	589 feet.
Little Mountain House, Lake County (conglomerate)	600 feet.
Summit near Akron, Summit County (conglomerate)	560 feet.
Hillsborough, Highland County (cliff limestone)	560 feet.
Coal Hill, Tallmadge, Summit County	625 feet.
Brookfield, Trumbull County (summits of hills)	590 feet.
Mantua, Portage County (summits of hills)	576 feet.
Summit Sandy and Beaver Canal, near Hanoverton, Columbiana County	634 feet.
Somerset, Perry County (conglomerate)	595 feet.
Greenville, Darke County (silurian limestone)	480 feet.
Summit of Blackwell's Fork and the Anglaise, Hancock County	488 feet.

Summit near Mechanicsburg, Champagne County	543 feet
Richland Village, northwest part of Richland County	498 feet.
Summit between waters of Beaver and Yellow Creek, Columbiana County	602 feet.
Hills adjacent to Salineville, Columbiana County	612 feet.
Canfield Academy, Mahoning County	612 feet.
River hills, Wellsville, on the Ohio	530 feet.
Hills adjacent to Yellow Creek line between Jefferson and Columbiana counties	680 feet,
National Road between Jacktown and Gratiot, Licking County	550 feet.
Hills south of Zoar, Tuscarawas County	648 feet.
Summit Cuyahoga and Chagrin Rivers, Geauga County	627 feet.
Norwich, Muskingum County	547 feet.
Summit between Sandusky River and Blanchard's Fork of the Anglaise	796 feet.
Tops of hills near Millersburg, Holmes County	660 feet.
Tops of hills near Newcastle, Coshocton County	750 feet.
Summit of Great Miami and Scioto Rivers, Logan County (about)	780 feet.
Northwest corner of Atwater, Portage County	601 feet.
New Chambersburg, Columbiana County (about)	650 feet.

Lime Rock No. One, of the Ohio Coal Series.

Like the coal, and all other strata of the Alleghany coal-field, the limestone beds are not continuous. For convenience, I designate them by numbers, reckoning from the lowest upward, with the caution that the same numbers do not necessarily indicate the same bed, but only their order of superposition. We have not yet acquired knowledge enough of the structure and extent of these strata to do better. It is very seldom that a bed of this lime rock occurs within one hundred feet of the bottom coal seam. In one instance, in Mr. Foster's profile, along the National Road lime rock No. 1 lies on coal seam No. 1,[1] at Brownsville, Licking County. Beginning at the Ohio River, in Lawrence and Scioto Counties, bed No. 1 is about one hundred feet above the lower coal. Constructing a geological section, from the Little Scioto south 60° east, to Symmes' Creek, thirty miles, I found in that distance three beds of limestone, four of coal, and seven of iron ore. The average dip is about twenty feet per mile, but in places it is locally much greater, the strata having many undulations. In Mr. Foster's section, from Columbus to Concord, in Muskingum County, a distance of seventy-five miles, course about east, there are five beds of limestone, and eight of coal. This is nearly on the line of dip, which varies from twenty-two to forty-eight feet per mile, average about thirty feet. Lime rock No. 1 here rests on the lower coal. Lime rock No. 2 is one hundred and forty feet above, and the *Buhr*, or "silico-calcareous mill-stone" bed, eighty-five feet higher. Following northerly along the western outcrop on the Walhonding, in Coshocton County, two miles south of Warsaw, lime rock No. 1 overlies the cannel coal only a few feet, at an elevation of four hundred and three feet above Lake Erie. A bed of bituminous coal intervenes between the cannel and the limestone. Three miles further south, at the head of Simmons' Creek, are two beds of limestone, one 425, the other 497 feet A, and two coal beds in close proximity, which are probably different from those in the cannel region. In the valley of the Killbuck, near Millersburg, Holmes County, the lower coal and lime rock are near each other; by estimate, within fifty feet. There certainly are three, and probably four beds of coal, and three of limestone, in the adjacent hills, which rise to six hundred and fifty feet above Lake Erie.

[1] See the Profile at the end of this article.

Triangulations for Dip of the Lower Coal Seam.

From the National Road northward, along the westerly and northwesterly border of the Ohio coal field, I have data for a connected series of planes, to the Pennsylvania line, at Brookfield, in the county of Trumbull. As the courses and distances between points are not obtained from maps of a large scale, they cannot be strictly accurate; neither are the levels, in all cases. But there are sources of error arising from the irregularity of the strata, which are fully as large as those of the surveys and elevations. The results are therefore put forward subject to future corrections, but with much confidence that they are close approximations.

Triangle No. 1. — Brownsville, Licking County, Newcastle, Coshocton County, and "Treaty Line," on the Killbuck, Holmes County. According to Mr. Foster's Report, the lower coal at Brownsville, on the National Road, is two hundred and seventy feet above Lake Erie. From thence to Newcastle, on the west line of Coshocton County, is north 9° east, 25.8 miles, and the elevation of the lower coal is there five hundred and thirteen feet above Lake Erie. From Newcastle to Cameron's Bank, at Treaty Line, four miles north of Millersburg, is north 32½° east, 22.2 miles. The base of this triangle, from Brownsville to Treaty Line, is 47½ miles, course north 20° east; the apex being at Newcastle. If we regard the upper Newcastle seam as the lowest of the coal series, the dip is seventy-one feet per mile, which is greater than I have anywhere discovered it in so large a plane. By using what Messrs. Winchell and Newberry regard as *a false coal seam*, near Newcastle, which is five hundred and thirteen feet above Lake Erie, as the *true* lower seam, corresponding to Brownsville and Massillon, it comes into harmony with other results. I therefore regard it as seam No. 1 of the series; the dip of which is south 69° east, 27½ feet per mile.

Triangle No. 2. — Darling's Bank, near Warsaw, Coshocton County, 348 feet A, Treaty Line, Cameron's Bank, and mouth of Newman's Creek, near Massillon. From Darling's, 348 A, to Treaty Line, 365 feet A, is north 15° east, 18 miles; Treaty Line to Massillon, 346 feet A, north 54½° east, is 23.3 miles. Base line, north 35° east, 39½ miles. The lower coal seam at these three points is so nearly level that the greatest dip is only two (2) feet per mile, direction south 55° east; the line of bearing coinciding with the base, from Darling's to Massillon.

Triangle No. 3. — Massillon, Coal Hill, Tallmadge, and Briar Hill. The central part of Coal Hill, Tallmadge, 505 feet A, is distant north 21° east from the mines at the mouth of Newman's Creek, 22.8 miles, and Briar Hill 318 feet A, north 65° east, 53 miles. In this plane the line of greatest inclination bears south 29½° east, at the rate of 9.9 feet per mile. Both the Massillon and the Briar Hill coal seams produce the best of iron when used in a raw state, and are therefore the most valuable beds in Ohio. If there was a reasonable certainty that this seam extended through, of the same quality, from the valley of the Tuscarawas to that of the Mahoning, it would furnish an inexhaustible supply. There are no valleys between those streams deep enough to cut the plane of coal seam No. 1; and the researches thus far made have failed to discover it.

Outline Geological Map.

Although from a bird's-eye view, Ohio appears as a vast plain, without mountain ranges, the outcrop of the strata present in their details very irregular lines; the hills and ridges are capped by beds which are so flat, that in the direction of the dip it may be ten or fifteen miles before the strata disappear beneath the valleys.

On a general map, the outline of the formations may be represented by a line drawn from one outlier to another; or it may be drawn midway between the outliers and the points where the strata sink to water level, as I have attempted to do in the present case. The true outline is very sinuous, with sharp projections and indentations, which can be correctly laid down only after tedious explorations, on plans of a large scale.

In that part of the coal region of Ohio west of the Muskingum and north of the Ohio River, Messrs. Briggs, Hildreth, and Foster traced out some prominent beds of the coal series, which they regard as continuous.

First, the Buhrstone. — From the line between Gallia and Jackson counties, in the township of Greenfield, it was followed northerly to the line between Athens and Vinton counties, in Waterloo; and thence, through Hocking and Perry a few miles east of Somerset, to the hills overlooking the Licking or Pataskala River, at the Falls, in Muskingum County, a distance of eighty-five miles.

Second, the Lower Limestone Group. — Dr. Hildreth traced a bed of fossiliferous lime rock, from a point six miles west of Gallipolis, northerly a little to the east of Athens, crossing the Muskingum River just above McConnelsville, from whence it bore more easterly, to the National Road, near Cambridge, in Guernsey County.

Several hundred feet above this is the great Pomeroy coal seam, which was recognized through the counties of Meig's and Athens, and the western part of Washington, to the Muskingum River, thinning out in that direction.

Third, the Upper Lime Group. — Several hundred feet above the Pomeroy seam is another marked limestone group, which appears on the Ohio at Letart's bend, and extends thence northeasterly, in a curved line parallel with the general course of the river, to the Muskingum, six or eight miles above Marietta. The profile from Cleveland to Wheeling, which accompanies this paper, shows the position of the great Pittsburg coal seam, on the upper Ohio. Messrs. Rogers of the Pennsylvania survey, and Briggs of that of Virginia, traced this bed along its outcrop on the Monongahela at Brownsville, down the valley to Pittsburg, where it rises to the tops of the hills; and thence across the Pan Handle to Steubenville. It does not, as I am aware, cross to the northwest side of the Ohio, above Steubenville, where on the Virginia side it is high in the hills. It dips southerly along the Ohio, at a rate which brings it down to high-water level at Wheeling. Above the Pittsburg seam, at a short distance, is a heavy bed of lime rock, or rather a group of calcareous strata, 40 to 60 feet in thickness. Below this coal seam is a no less marked bed of sand rock, 300 to 400 feet in thickness, which produces no workable coal, and is therefore called in Pennsylvania and Virginia, "the barren sandstone" group, or the lower sand rock. As yet neither the Pittsburg seam nor the upper lime group have been identified on the Muskingum.

Professor E. B. Andrews, of Marietta, after much local examination in that quarter, finds a north and south line of disturbance near the valley of Duck Creek, a few miles east of the Muskingum. This disturbed country, extending from Noble County, across the river Ohio, to the "Burning Spring," on the waters of Little Kanhawa, is the seat of petroleum springs and wells.

It is therefore not settled whether the upper lime group of Dr. Hildreth corresponds to that above the Pittsburg seam at Wheeling. It is scarcely supposable, that so heavy a bed would disappear in the intermediate distance of sixty miles. Another prominent bed of lime rock exists in the northwest part of Jefferson County, crossing Yellow Creek a few miles above its mouth in Columbiana County, which is sometimes called the white limestone, being of a lighter color than the blue. It is about three hundred feet above the "big vein" of the Yellow Creek system.

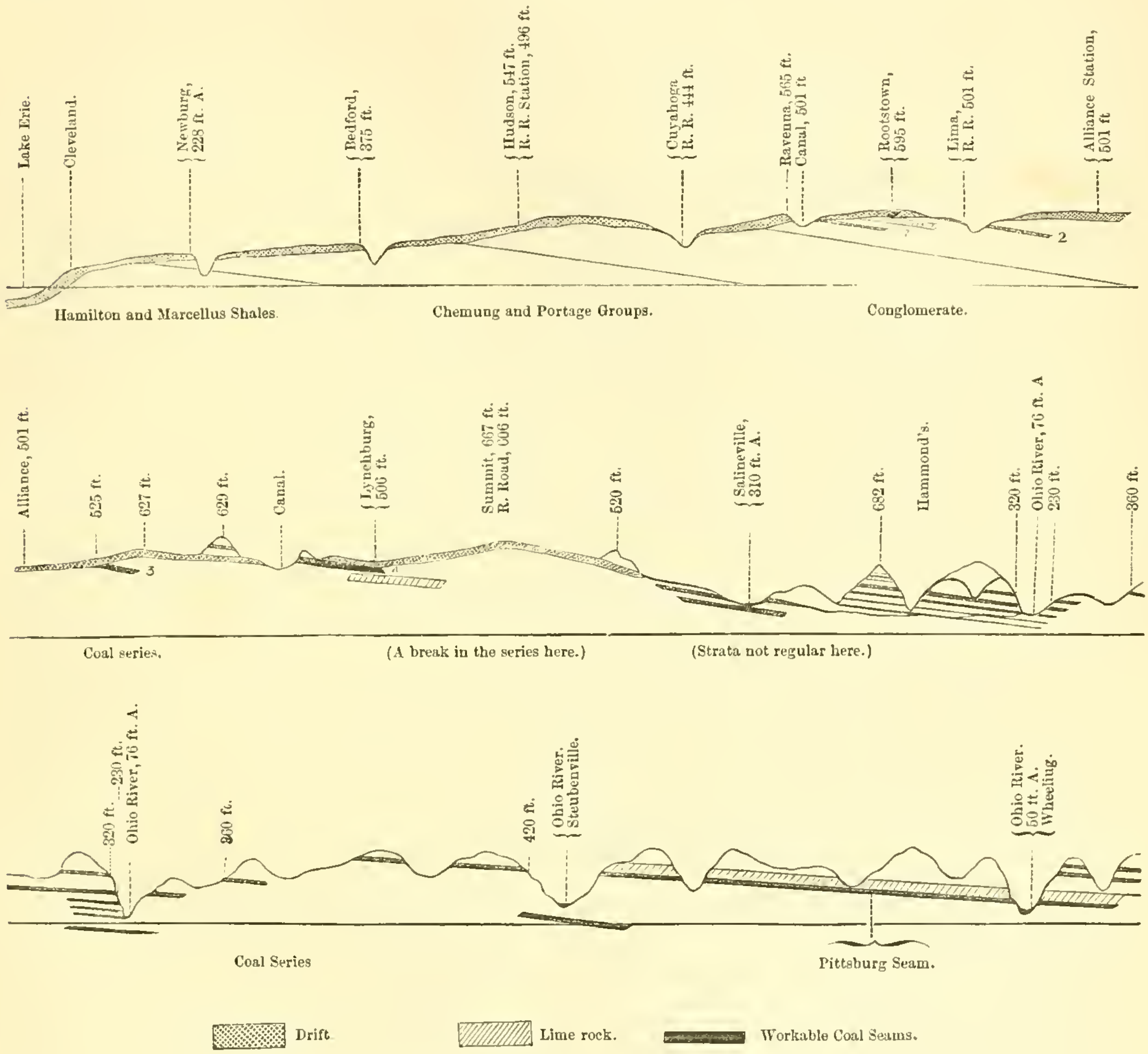
That portion of the State between Yellow Creek and the Muskingum, although it is rich in coal seams, has been less studied geologically than any other part of it. For the purpose of mapping the strata, the great barren group of sandstone, below the Pittsburg seam, would furnish a good horizon of reference, and when it is traced through Ohio, the position of this important coal seam in this State, or at least the point of its disappearance, may be determined. In a region geologically so irregular, nothing short of connected explorations will fix the identity of strata between distant points. That portion of the Ohio coal-field north of the railway from Coshocton to Steubenville seems to have been an expansion of the carboniferous seas, in which the deposits were left by local eddies in the form of very disconnected basins and troughs, between which there are spaces barren of coal. My field-books show instances where the ancient currents of the coal era had made excavations in the original mud of the shaly deposits, afterwards filled in by other materials. The buhrstone beds in this portion of the field are not traceable over long lines, but, like the other strata, are quite local, and exist at various geological levels. In Tuscarawas County, west of New Philadelphia, there is an outcrop a few miles in length. There is another near Alliance, in Stark County, from which, as from the buhr of Muskingum County, the aborigines quarried the rock, for flint arrow and spear heads. Another limited outcrop is seen on the Alleghany River, about twenty miles below Franklin, Pa.

When the barren sandstone group next below the Pittsburg seam is followed southerly, it is probable it will be found to recross the Ohio River near Marietta, separating the Pittsburg and Wheeling coal from the Pomeroy. Should this prove to be the case, the upper limestone group of Dr. Hildreth will represent the Wheeling group in diminished thickness, and a seam of coal on the Muskingum below Waterford, the Pittsburg seam. In the profile made by Professor Andrews, along the Marietta and Cincinnati Railway, from the lower coal seam in the north part of Jackson County, nearly east to Marietta, there are eight (8) seams represented, three of which are heavy and extensive. This profile has not yet been carried up to the great Wheeling and Pittsburg bed, with which the profile on the opposite page is connected. There is also a vacant space of about fifty miles between the eastern end of the profile made by Mr. Foster, along the National Road, which terminates at the east line of Muskingum County, and Wheeling. Another profile is very much needed across the intermediate space north of the National Road, and south of the Sandy and Beaver Canal, along the railway from Coshocton to Steubenville, where it would connect with the Pittsburg seam.

[That part of the accompanying map, Plate 24, which lies south of the National Road, is compiled from the Ohio Reports of 1838 and 1839.]

Published March, 1869.

GEOLOGICAL PROFILE OF THE STRATA FROM CLEVELAND TO THE OHIO RIVER ALONG THE PITTSBURG R. R., 100 MILES S. EAST; THENCE TO WHEELING 35 MILES SOUTH — SCALE SEVEN MILES TO THE INCH. LAKE LEVEL 564 FEET ABOVE TIDE WATER MARK.



Numbers 1 to 4 refer to coal seams.

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ERRATA.

Page 25, line 1, for *diameter* read *length.*
" 46, line 3, for *T* read *IT.*
" 107, lines 29–30, for *only eleven species are quoted* read *eleven species are quoted only.*
" 108, last line, for *break* read *beak.*
" " last line but one, for *relations* read *alations.*
" 131, line 4. for *I* read *V.*
" 135, " 14, supply *a* at the beginning of the line.
" 179, " 38, for *Neuroptera* read *Nemoptera.*
" 193, " 30, supply *of* at the end of the line.
" 246, " 12, for Plate VIII read Plate VII.
" 281, " 27, for *Solenensis* read *Solen ensis.*
" 358 et seq., for *Puawaina* read *Puoaina.*
" 373, last line, for *Kalapanu* read *Kalapana.*
" 382, line 19, for *Hieracium* read *Sonchus.*
" 398, " 7, for *masses of* read *masses or.*
" 471, for *Puawaina etc.* read *Puoaina, earthswelling.*
" 485, last line, for *containing* read *contain.*

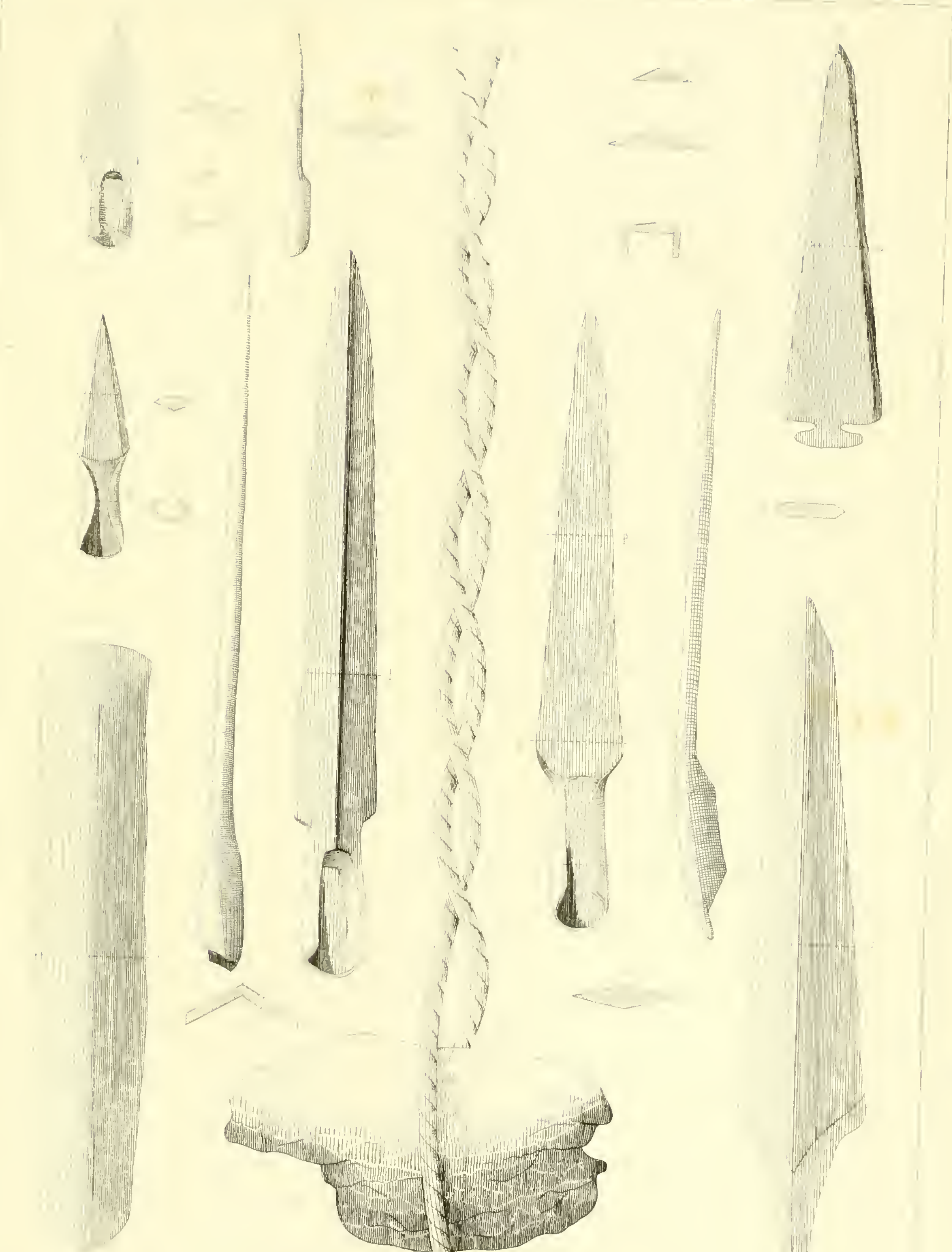
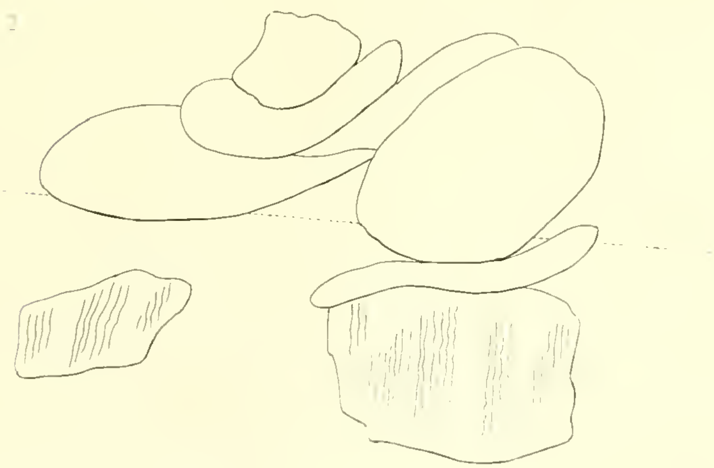


FIG 1

FIG 2

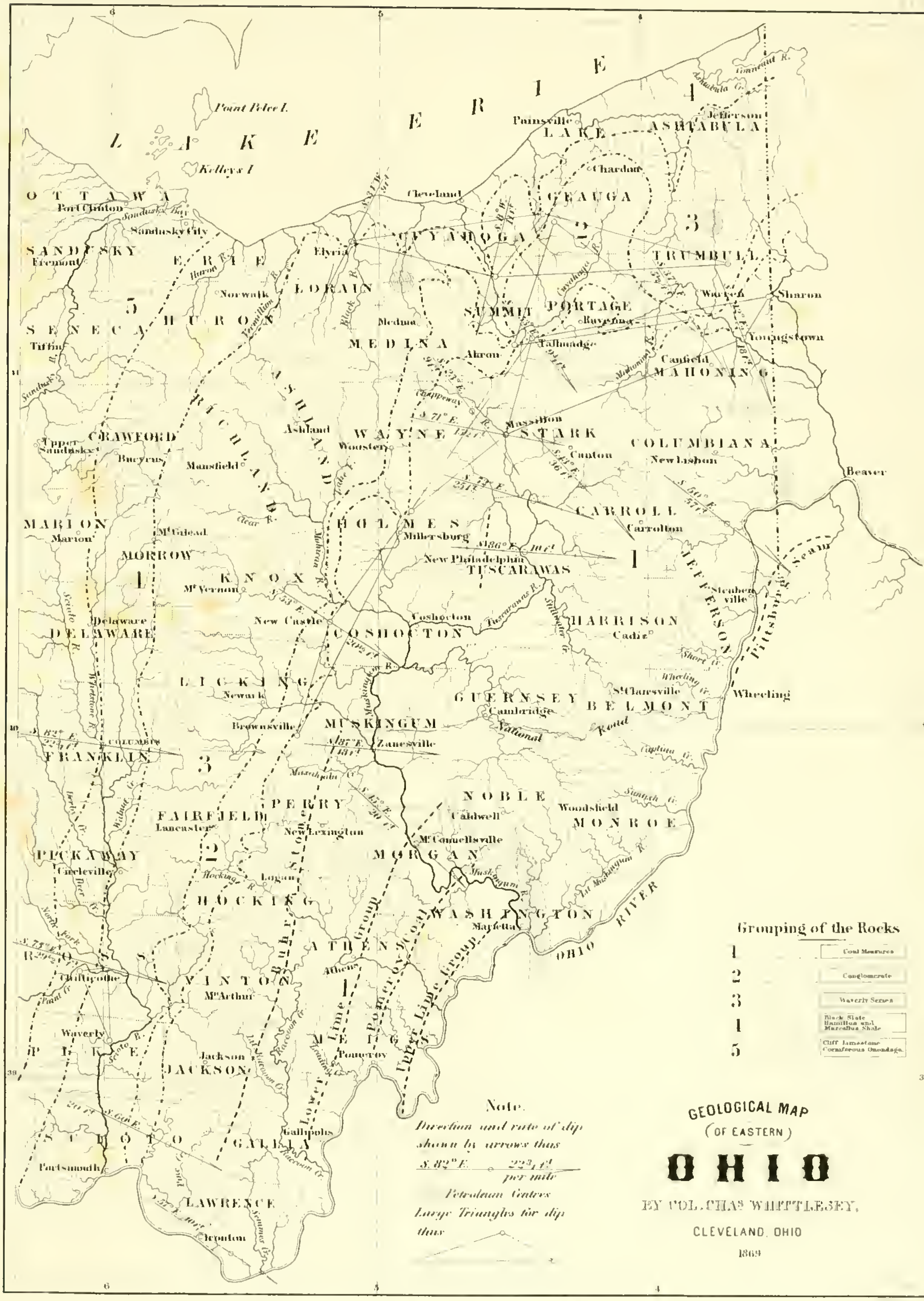


...se on the distortion of pebbles in conglomerates

FIG 1

FIG 2

ALSINIDENDRON TRINERVE H. MANN


GEOLOGICAL MAP (OF EASTERN) OHIO
BY COL. CHAS WHITTLESEY,
CLEVELAND, OHIO
1869
Grouping of the Rocks
1 Coal Measures
2 Conglomerate
3 Waverly Series
4 Black Slate Hamilton and Marcellus Shale
5 Cliff Limestone Corniferous Onondaga
Note.
Direction and rate of dip shown by arrows thus
S. 82° E. 22 3/4 ft per mile
Petroleum Centres
Large Triangles for dip thus
LAKE ERIE
Point Pelee I.
Kelleys I.
OTTAWA
SANDUSKY
SENECA
ERIE
HURON
LORAIN
CUYAHOGA
GEAUGA
LAKE
ASHTABULA
TRUMBULL
SUMMIT
PORTAGE
MEDINA
MAHONING
WAYNE
STARK
COLUMBIANA
CRAWFORD
RICHLAND
ASHLAND
HOLMES
CARROLL
MARION
MORROW
KNOX
TUSCARAWAS
JEFFERSON
HARRISON
DELAWARE
COSHOCTON
LICKING
GUERNSEY
BELMONT
MUSKINGUM
FRANKLIN
FAIRFIELD
PERRY
NOBLE
MONROE
PICKAWAY
MORGAN
HOCKING
WASHINGTON
ATHENS
ROSS
VINTON
MEIGS
PIKE
JACKSON
SCIOTO
GALLIA
LAWRENCE
OHIO RIVER
National Road
Lower Lime Group
Upper Lime Group
Pomeroy Coal
Painsville
Jefferson
Chardon
Cleveland
Port Clinton
Sandusky City
Fremont
Elyria
Norwalk
Tiffin
Medina
Ravenna
Warren
Sharon
Youngstown
Canfield
Akron
Tallmadge
Massillon
Canton
Ashland
Wooster
Mansfield
Bucyrus
Upper Sandusky
New Lisbon
Beaver
Carrollton
Millersburg
Marion
Mt. Gilead
New Philadelphia
Mt. Vernon
Steubenville
Delaware
New Castle
Coshocton
Cadiz
Newark
St. Clairsville
Wheeling
Cambridge
Brownsville
Zanesville
Columbus
Lancaster
New Lexington
Caldwell
Woodsfield
Circleville
Mc Connellsville
Logan
Marietta
Athens
Chillicothe
Mc Arthur
Waverly
Jackson
Pomeroy
Gallipolis
Portsmouth
Ironton