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DEPARTMENT OF THE INTERIOR

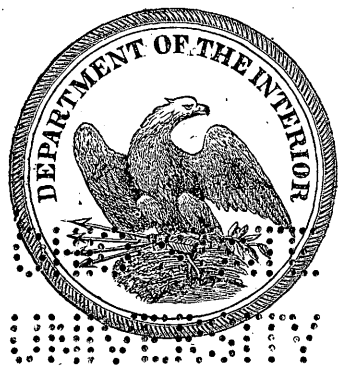
BULLETINS

OF THE

UNITED STATES

GEOLOGICAL SURVEY

VOL. V



WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

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ILLUSTRATIONS.

ADVERTISEMENT.

[Bulletin No. 31.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that —

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is specially supplied to this Office by the Secretary of the Interior, the Survey has no copies of any of its publications for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

The Sixth Annual Report is in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, and IX are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 164 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price, $1.15.

The following are in press, viz:

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 237 pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl.

XII. Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

— Lake Bonneville, by G. K. Gilbert.

— Sauropoda, by Prof. O. C. Marsh.

— Stegosauria, by Prof. O. C. Marsh.

— Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker.

— The Penokee-Gogebic Iron-Bearing Series of North Wisconsin and Michigan, by Roland D. Irving.

— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.

— Younger Mesozoic Flora of Virginia, by William M. Fontaine.

— Report on the Denver Coal Basin, by Samuel F. Emmons.

— Report on Ten-Mile Mining District, Colorado, by Samuel F. Emmons.

— Report on Silver Cliff Mining District, by Samuel F. Emmons.

— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient sizes. To facilitate this, each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 31 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11 On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Dr. C. A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by J. M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, by Arnold Hague and J. P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Dr. C. A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White, M. D. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. The Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by W. H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 82 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Work done in the division of Chemistry and Physics mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md., by George H. Williams. 1886. 8°. 78 pp. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Dr. C. A. White. 1886. 8°. 42 pp. Price 5 cents.

30. Second contribution to the studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 379 pp. pl. Price 25 cents.

31. A systematic review of our present knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; and Numbers 24 to 30, Volume IV. Volume V is not yet complete.

The following are in press, viz:

32. Mineral Springs of the United States, by Albert C. Peale, M. D. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by Joseph S. Diller.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Dr. Charles A. White.

35. The Physical Properties of the Iron Carburets, by Carl Barus and Vincent Strouhal.

36. The Subsidence of small particles of Insoluble Solid in Liquid, by Carl Barus.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1,016 pp. Price 60 cents.

In preparation:

Mineral Resources of the United States for calendar year 1885, by Albert Williams, jr.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE or MONEY ORDER (not stamps), should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *September* 1, 1886.

DEPARTMENT OF THE INTERIOR

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UNITED STATES

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No. 31

WASHINGTON
GOVERNMENT PRINTING OFFICE
1886

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

SYSTEMATIC REVIEW

OF OUR

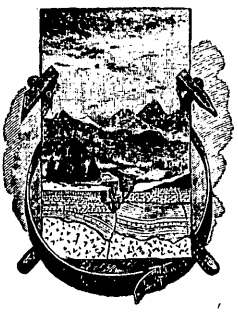
PRESENT KNOWLEDGE OF FOSSIL INSECTS

INCLUDING

MYRIAPODS AND ARACHNIDS

BY

SAMUEL HUBBARD SCUDDER



WASHINGTON

GOVERNMENT PRINTING OFFICE

1886

CONTENTS.

LETTER OF TRANSMITTAL.

CAMBRIDGE, MASS., *January* 13, 1886.

SIR: I have the honor to transmit for publication as a bulletin of the Survey the inclosed systematic review of our present knowledge of fossil insects, including myriapods and arachnids.

While much fuller in the modern orders and families, the following pages represent the English text furnished to Dr. Zittel for his Handbuch der Palæontologie, where the section forms the closing pages of the second part of the first volume (pp. 721–831) and is accompanied by more than two hundred illustrations. The present bulletin is issued, with the concurrence of Dr. Zittel and the publisher of the Handbuch, for the convenience of English readers. A French version, under the auspices of M. Barrois, is also in course of simultaneous publication. The present is its original form and is the authoritative English edition.

I am, very truly, yours,

SAMUEL H. SCUDDER.

Hon. J. W. POWELL,
Director United States Geological Survey.

SYSTEMATIC REVIEW OF FOSSIL INSECTS.

MYRIAPODA.

BIBLIOGRAPHY.

Bertkau, P. Einige Spinnen und ein Myriapode aus der Braunkohle von Rott. Verhandl. d. naturh. Vereins d. preuss. Rheinl. [4.] Band IV. Taf. 5. 8vo. Bonn, 1878.

Dawson, J. W. On a chilognathous myriapod from the coal formation of Nova Scotia Quart. Journ. Geol. Soc. Lond. Vol. XVI. Figs. 8vo. London, 1869.

Dohrn, A. Julus Brassi. Verhandl. d. naturh. Vereins d. preuss. Rheinl. [3.] Band V. Taf. 6. 8vo. Bonn, 1868.

Giebel, C. G. Die Insecten und Spinnen [incl. Myriopoden] der Vorwelt. 8vo. Leipzig, 1856.

Koch, C. L., and *Berendt, J. C.* Die im Bernstein befindlichen Crustaceen, Myriapoden, Arachniden und Apteren der Vorwelt. 17 plates (2 Myriap.). Fol. Berlin, 1854. Contains many additions by Menge.

Meek, F. B., and *Worthen, A. H.* Articulated fossils of the coal measures. Geol. Survey of Illinois. Vol. III. Figs. 8vo. Springfield, 1868.

Peach, B. N. On some fossil myriapods from the lower old red sandstone of Forfarshire. Proc. Roy. Phys. Soc. Edinb. Vol. VII. Pl. 2. 8vo. Edinburgh, 1882.

Scudder, S. H. On the Carboniferous myriapods preserved in the Sigillarian stumps of Nova Scotia. Mem. Bost. Soc. Nat. Hist. Vol. II. Figs. 4to. Boston, 1873.

——— Archipolypoda, a subordinal type of spined myriapods from the Carboniferous formation. Ibid. Vol. III. Pl. 10–13. 4to. Boston, 1882.

——— The affinities of Palæocampa. American Journ. Science. [3.] Vol. XXIV. 8vo. New Haven, 1882.

——— Two new and diverse types of Carboniferous myriapods. Mem. Bost. Soc. Nat. Hist. Vol. III. Pl. 26–27. 4to. Boston, 1884.

Woodward, H. On Euphoberia Brownii. Geol. Mag. Vol. VIII. Pl. 3. 8vo. London, 1871.

CHARACTERISTICS AND PHYLOGENY.

Myriapoda are vermiform articulates in which the head proper is composed of a single mass (sometimes supplemented by subsidiary parts borrowed from the segments immediately succeeding the head), while the rest of the body is composed of a series, generally of a long series, of very similar rings, each bearing one or two pairs of jointed legs, terminating in a claw, with rare exceptions single. No thorax is differentiated. The head is furnished with short and generally very simple antennæ, agglomerated ocelli, and two pairs of movable organs forming the mouth. In one group (Chilopoda) two pairs of appendages on succeed-

ing rings become subservient to manducation. Respiration is effected through spiracles on the body segments.[1] The body is usually hard and chitinous.

Our knowledge of the morphology, systematic position, and extent of the Myriapoda has been greatly increased within a recent period. The discovery of the minute Pauropus by Lubbock and the study of this and allied forms by Ryder and others have led to the establishment of the Pauropoda as a type of living myriapods of equal taxonomic value with the two groups Chilopoda and Diplopoda, which had long been looked upon as the only divisions of the group. Modern investigations into the structure of the anomalous Peripatus have extended our ideas concerning the types allied to the Myriapoda; while the strange forms revealed by recent researches in the Carboniferous and Devonian faunas have compelled us to recognize a wider range in its structure and a multiplication of its primary groups. The relations of ancient to modern forms of life prove far more important and interesting in the Myriapoda than in either the Arachnida or the Hexapoda. That these relations are equally puzzling will appear from a brief review of the structure and development of the different groups.

In the early life of the Pauropoda and of the Diplopoda we have what may be fairly considered a true larval form, in which, for a brief period after leaving the egg, the body, much shorter than in after-life, is provided with three pairs of legs borne upon the anterior segments of the body. These segments are never more fully provided with legs, though most of the segments posterior to them, both those which exist during this larval period and those which originate subsequently, bear each two pairs. In the Chilopoda, on the other hand, although the appendages of the anterior segments develop earlier than those behind them, there is no true larval condition, or perhaps one may say a larval condition is permanent, in that the same anterior legs become early and permanently developed as organs subsidiary to manducation, while each segment of the hinder part of the body develops only a single pair of legs.

The larval condition and resultant more or less highly developed metamorphosis of the higher Hexapoda have been looked upon by many as secondary after-developments, which therefore in no sense give any clew to the historical development of the group, such as we frequently find mirrored in the embryonic growth of other animals. This view seems to be supported by a comparison of the modern and ancient types of Myriapoda. The larval characteristics of the young of living types of Myriapoda, marvelously analogous in their main features to those of the larvæ of even the higher Hexapoda, are confined to the apodal nature of the abbreviated abdomen, and more particularly to the specialized development of appendages on the segments directly

[1] Tracheal openings have not been observed, however, in the Pauropoda.

following the head. This specialized condition of the anterior segments is, in a sense, analogous to the structure of the thorax of the Hexapoda, and is persistent throughout life: in the Chilopoda in a marked manner, in the other groups by the isolation of these segments as bearing each but a single pair of legs. Now, nothing of this specialization appears in the Paleozoic types, of which of course we know only the mature forms; but the segments following the head differ in no point whatever from those of the remainder of the body in the character and number of their appendages. In one type, the Archipolypoda, corresponding in a measure to the living type of Diplopoda, two pairs of legs are borne on every segment; while on each segment of the other, the Protosyngnatha, corresponding in a similar way to the Chilopoda, a single pair of legs is found. If, then, we look upon the specialization of the segments (or the appendages of the segments) immediately following the head in living myriapodan types as a secondary development, or, we may say, as the initiatory stage in an acquiring metamorphosis, then we may perhaps consider the Archipolypoda as the true prototypes of the Diplopoda and possibly also of the Pauropoda, and the Protosyngnatha as the prototypes of the Chilopoda.

In this view, one principal distinction between the modern Diplopoda and Chilopoda is shown to have existed from Paleozoic times, viz, that in one group there are, over most of the body, to each dorsal scute two ventral scutes, each bearing a pair of legs; in the other group a single ventral scute with a single pair of legs; and it becomes interesting to inquire whether we can discover any indication of the condition of things from which this diversity of structure arose and what was the line of development through which it passed. It will also help to determine the question whether the dorsal or the ventral scutes of the Diplopoda are to be looked upon as the homologues of those of the Chilopoda; or, in other words, whether the dorsal scutes of the Diplopoda are compound or the ventral scutes of the same are to be looked upon as subsegments.

It should be remarked at the outset that what we know of the embryology of recent types shows that in the Diplopoda two pairs of legs, in the Chilopoda one pair, arise from each original body somite beyond the front portion of the body. This would indicate that the dorsal scutes of the two groups are homologous and that the ventral scutes of the Diplopoda should be looked upon as representing subsegments. This, however, is not the answer indicated by the paleontological evidence, nor is it what we should expect, among other things, from the presence of stigmata on each of the ventral scutes in Diplopoda.[1] All the Carboniferous Archipolypoda show a clear indication of the compound nature of the segments. Not only were the ventral scutes far more important and extensive than in the modern Diplopoda, but some at least of the genera, in addition to large stigmata outside the legs,

[1] They are only borne in general on alternate segments in Chilopoda.

bore a pair of segmental organs next the medioventral line on each ventral scute; the dorsal scute was also distinctly divided into two areas, an anterior and a posterior. In some types this latter distinction was more marked than in others, in some being carried so far that under certain conditions of preservation one would readily take them to be entirely separate; and this indeed appears to be absolutely the case in the older Devonian forms, from the lower old red sandstone of Scotland. These show an apparently complete demarkation of the dorsal as well as of the ventral scutes of each segment, and present therefore a series of alternating larger and smaller segments, the larger bearing all the dorsal cuticular outgrowths, but each bearing a single pair of legs. Of this primal condition of the body segments the embryology of modern types gives no hint, its earliest indications showing nothing anterior to what must have been the condition of things wholly posterior to the Paleozoic epoch, at least so far as the diplopodan series is concerned; nothing anterior, indeed, to the fixed condition of the present type. This indicates that the present dorsal scutes of Diplopoda are compound and formed of two originally distinct scutes; and that, as a later development of a similar sort, the ventral scutes of the anterior segments have likewise consolidated and lost each one pair of appendages.

Under this view the line which we follow back from the Chilopoda through the Protosyngnatha is the more nearly allied to the simple stock type. Yet it is the other line which has been found earliest in the rocks, clearly showing that the actual origin of the myriapodan phylum must be looked for at the very first appearance of land animals; indeed, the evidence that some of the Carboniferous types were amphibious may warrant our belief that the type may have fairly originated among aquatic animals.

Fossil Myriapoda were first made known from the Carboniferous rocks when Westwood figured, in Brodie's work on the older fossil insects of England, the remains of what he supposed to be a lepidopterous larva. There had been indeed earlier references, by name merely, to Tertiary Myriapoda from amber and from Aix (by Serres), but it was not until the publications, thirty years ago, of Koch, Berendt, and Menge that the amber species were known, and to them hardly any additions have since been made. In 1859 Sir William Dawson published the first account of a Paleozoic myriapod recognized as such, and since 1868 our horizon, as regards the older forms, has been widened materially by the publications of Messrs. Dohrn, Meek and Worthen, Peach, Scudder, and Woodward, until to-day the number of forms known from Pretertiary deposits is nearly as great as that from the Tertiary.

The oldest known are those described by Page and by Peach from the lower old red sandstone of Scotland, two species belonging to the Archipolypoda. In the Carboniferous formation the Archipolypoda culminate, showing a considerable variety of generic types distinct from those

of the Devonian and embracing nearly thirty species, of which by far the greater number come from America, and the few remaining ones from Great Britain, with possibly a single species from Germany. Four species, imperfectly known, which have been referred to Julus and which come from the Permian of Central Europe, may belong to the Archipolypoda. The only Mesozoic forms known are *Julopsis cretacea* of Heer, from Greenland, which is either an archipolypod or a diplopod (it is impossible to tell which), and the uncertain *Geophilus proavus* of Münster, from Solenhofen, which is probably to be looked upon as a nereid worm.

The Tertiary species are still known almost entirely from the work of Koch and Berendt and belong entirely to the Diplopoda and the Chilopoda, the larger proportion to the former. A few species, however, have been indicated from Aix, a single one described from the brown coal of Rott and one from the Green River deposits of North America.

The following table presents a view of the distribution of the Myriapoda in time:

Geological distribution of Myriapoda.[1]

Groups.	Paleozoic.			Mesozoic.			Cenozoic.				Modern period.
	Devonian.	Carboniferous.	Dyas.	Lias.	Jura.	Cretaceous.	Eocene.	Oligocene.	Miocene.	Pliocene.	
Protosyngnatha	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	0
Chilopoda	.....	.....	.....	.....	(1?)	.....	.....	17	.....	.....	.....
Archipolypoda	2	31	(4?)	.....	.....	.....	.....	.....	.....	.....	0
Diplopoda	.....	.....	.....	.....	.....	(1?)	.....	23	1	.....	.....
Pauropoda	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

[1] The figures represent the number of species.

1. Order **PROTOSYNGNATHA** Scudder.

Paleozoic myriapods, with a cylindrical, not very elongated body, composed of few segments, the head appendages borne upon a single apparent segment; each body segment, including those immediately behind the head, composed of a single dorsal and a single ventral plate of equal length and of subequal breadth; each segment has a pair of widely-separated, stout, fleshy legs; and, above, large tubercles supporting a cluster of long needles are arranged in longitudinal rows.

This group of ancient myriapods is known through a single form found sparingly in a single locality in America. It was at first looked upon as the caterpillar of a lepidopterous insect (as was also the case with the longest known archipolypod) and afterward as a worm. Its armature seems even stranger for a myriapod than the spines of the

Archipolypoda, and the intimate structure of the single needles is remarkably complicated.

Palæocampa Meek and Worthen. Body composed of ten segments; spreading fascicles of needle-like spines arranged in dorsolateral and lateral rows, one to a segment in each row; needles exceedingly slender, scarcely tapering, blunt at tip, and very regularly divided by longitudinal serrated ridges. The spines are only a tenth of a millimeter in diameter; those on the front segments are directed forward and those on the last segments backward, giving specimens which are well preserved a very close general resemblance to a caterpillar of the genus Arctia. *Palæocampa anthrax* Meek and Worthen, Mazon Creek, Ill.

2. Order **CHILOPODA** Latreille.

Body elongated, more or less depressed, of nearly uniform width, composed of many segments, the head appendages borne upon two or more apparent segments, the anterior feet being transformed into organs subsidiary to manducation; each body segment composed of a single large dorsal and almost equally large ventral plate connected by membranous cuticle, to which are attached a single pair of legs on each segment and a spiracle generally on alternate segments. The legs are, therefore, lateral and widely separated at base. No spines are present, but sometimes lateral expansions of the dorsal plate. Sexual organs at posterior extremity of body.

With the exception of the dubious *Geophilus proavus* Münster, from the Jura of Solenhofen, which is probably not a myriapod at all, the earliest appearance of this type of existing myriapods is in the amber deposits of Prussia, where a considerable number of species have been found, nearly equaling, indeed, the Diplopoda of the same deposits, although, at the present day, the latter group far outnumbers them. A few specimens referred to Scolopendra have been reported from other Tertiary beds in Europe.

Cermatiidæ.—Two species of Cermatia occur in amber.

Lithobiidæ.—A considerable number of species, all referred to Lithobius, have been found in amber. Koch and Berendt describe and figure three species, to which Menge adds seven others very briefly described in notes to Berendt's work. The genus is, therefore, the richest in species among Tertiary myriapods.

Scolopendridæ.—Menge describes a single species of Scolopendra from amber and mentions a second. Sendel also figures one from amber, and it is referred to by subsequent authors. According to Keferstein, Aldrovandus mentions the discovery of a fossil Scolopendra near Glarus, Switzerland, and Hope mentions one as found at Aix.

Geophilidæ.—Three species of Geophilus are briefly described by Menge from amber, but none of these have been figured. *Geophilus*

proavus Münster, from the Jura of Solenhofen, is, as stated above, dubious, but, if it belongs to the myriapods, it will probably fall in this place.

3. Order **ARCHIPOLYPODA** Scudder.

Paleozoic myriapods, with a fusiform elongated body, largest at the middle of the anterior half or third, composed of many segments; the head appendages borne upon a single apparent segment; the body segments, including those immediately behind the head, composed of a pair of ventral plates and a more or less divided dorsal plate, the latter occupying the upper surface and most of the sides of the body and divided more or less conspicuously into a ridged anterior and a lower posterior portion, the anterior frequently bearing spines or tubercles; the ventral plates as broad as the body, each bearing a pair of long corneous legs approximated at base and furnished outside of them with large spiracles, the mouth of which lies transverse to the body.

This is the most important group of ancient myriapods, having been well represented in the Paleozoic rocks, though unknown later. Indeed, with a single exception, all the known Paleozoic myriapods belonged to this type, and several families are known, of which one belonged exclusively to the Devonian. The Carboniferous Archipolypoda appear to have been far more numerous in the New than in the Old World.

1. Family **Archidesmidæ** Peach.

Dorsal plates hardly consolidated, the two portions appearing as if forming completely distinct parts, but the anterior marked by its greater importance and development. Body supplied with more or less marked laterally expanding lamellæ on the anterior division of the segments.

This group of ancient myriapods is confined, as far as known, to the Devonian formations of Scotland.

Kampecaris Page. Body cylindrical or slightly depressed, tapering but little anteriorly; lateral lamellæ inconspicuous, the anterior subsegments not greatly larger than the posterior. *Kampecaris Forfarensis* Page, from the lower old red sandstone of Forfarshire, Scotland. This species was taken by Page for an isopod crustacean, but referred to its true position by Peach.

Archidesmus Peach. Body fusiform, depressed, the anterior subsegment much larger than the posterior, its pleural walls produced laterally into large rounded lamellæ. *Archidesmus Macnicoli* Peach, from the same locality as the preceding.

2. Family **Euphoberidæ** Scudder.

Dorsal plates more or less closely consolidated, but distinctly separable into two portions, one much more elevated than the other. Body

armed with large spines, often forked, occasionally reduced to broad tubercles, extending in several longitudinal series.

This family of Carboniferous Myriapoda includes the gigantic bristling species, some of which, at least, were amphibious, being provided with segmental organs, which were apparently branchial in character, besides ordinary spiracles, and with lamellate legs adapted for either aquatic or terrestrial locomotion. They appear to have been far more abundant in the New World than in the Old, and in the latter are little or not at all known outside of Great Britain.

Acantherpestes Meek and Worth. Spines bifurcate at tip and arranged in dorsal, pleurodorsal, and lateral rows; segments three or more than three times as broad as long. *Acantherpestes major* Meek and Worth., Mazon Creek. This species attained the extraordinary length of three decimeters and was armed with coarse branching spines more than a centimeter long. It was on this species that the problematical segmental organs were found, consisting of a pair of subtriangular, rounded, approximated, infundibuliform openings on either side of the median line between the legs and much smaller than the linear stigmata. *A. Brodiei* Scudd., Coalbrookdale, Eng. This species was considered at first by Westwood as the caterpillar of one of the Saturnidæ, a family of Lepidoptera; afterwards, by Woodward, as one of the Merostomata. Perhaps *Chonionotus lithanthracis* Jordan, from Saarbrück, belongs here.

Euphoberia Meek and Worth. Spines spinuliferous, but with a single-pointed tip, arranged in subdorsal and lateral rows; segments generally from two to three times broader than long. About a dozen species are known, mostly from Mazon Creek, Ill. Two species occur in England.

Amynilispes Scudd. Spines simple, arranged in dorsolateral rows; segments four times as broad as long. *Amynilispes Worthieni* Scudd., from Mazon Creek.

Eileticus Scudd. No spines, but large low tubercles, serially arranged; segments few, less than twice as broad as long. *Eileticus anthracinus* Scudd., from Mazon Creek.

3. Family Archiulidæ Scudder.

Dorsal plates closely consolidated, but still distinctly separable, though the anterior is rarely elevated much above the other. Body almost smooth or covered more or less abundantly with serially-disposed papillæ, from which in some cases hairs or small spines arise.

The members of this family resemble modern Diplopoda in their general appearance much more closely than either of the preceding families. The indications of spines or spinous hairs upon the sides of the body, the fusiform shape of the body, the length of the legs, and the indications in some of them of great breadth to the ventral plates present so many points of affinity to contemporaneous forms that they

should be classed with the Archipolypoda. They are, however, still insufficiently known. Mostly occurring in America, they have also been found in Great Britain and on the continent of Europe.

Archiulus Scudd. Segments entire, of very variable size, but generally from two to three times broader than long, furnished with a few bristle-bearing papillæ. Four or five species are known to me from different parts of America, three coming from the sigillarian stumps of Nova Scotia. *Julus Brassi* Dohrn, from Lehbach, probably belongs here (or in the next genus), and perhaps also the three species of Julus named by Frič, from the Dyas of Bohemia. (*Palæojulus dyadicus* Gein., from the Dyas of Saxony, has been shown by Sterzel to be a fern, and Trichiulus, described by Scudder, from the American Carboniferous, also turns out to be a fern leaf.)

Xylobius Daws. Segments as in the preceding genus, but broken by longitudinal sutures into numerous quadrate frustra. Four species are known from the sigillarian stumps of Nova Scotia, besides two species (unpublished) from Mazon Creek and one from England.

4. Order **DIPLOPODA** Gervais.

Body elongated, usually cylindrical, of nearly uniform size, the head appendages borne upon a single apparent segment; each body segment composed of a single dorsal plate of great size, shorter below than above, corresponding to which there are two minute, narrow (rarely moderately broad) ventral plates, each bearing a pair of spiracles and of legs, excepting on the anterior segments, where there is only a single pair of legs to each dorsal segment; the legs are therefore inferior and approximate at base. No spines, but occasionally roughnesses and ridges or setæ on dorsal plates. Sexual organs situated anteriorly.

This family, by far the most abundant at the present day, was richer than the Chilopoda during Tertiary times, both in genera and species. Its earliest record is in the Cretaceous, a species figured by Heer, from Greenland, probably belonging here rather than in the Archipolypoda. Most of the Tertiary species are known only from amber.

Glomeridæ.—*Glomeris denticulata* Menge, from amber, is the only species known and is very briefly described.

Polydesmidæ.—Menge merely mentions the occurrence of two species of Polydesmus in amber.

Lysiopeltidæ.—Of this interesting family, Menge describes from amber six species of Craspedosoma, besides one figured by Koch and Berendt, and a distinct genus, Euzonus, with one species, *E. collulum*, also from amber, in which the body tapers considerably toward the head and at the tail; the antennæ are twice as long as the breadth of the head, with the first and seventh joints smallest and the third and fifth largest, the eyes consisting of twenty ocelli, set in a semicircle behind the antennæ.

Julidæ.—Koch and Berendt describe a single species of Julus from amber; Menge, in his notes to their work, describes briefly three others; Gravenhorst and others mention also the occurrence of a species of this genus in amber, and several species have also been found in Tertiary rocks. Thus Cotta refers to the living *Julus terrestris* a form found at Tharand, Saxony, concerning which it is questionable whether it be a fossil. Serres compares to the living *Julus sabulosus* a species found in the lacustrine limestones in the neighborhood of Montpellier. Hope mentions Julus as found in the marls of Aix, without further reference. But besides these, one species, (*J. antiquus* Heyden) has been described from the brown coal of Rott, and another (*J. telluster* Scudd.), from the Green River shales of Wyoming. Menge also briefly describes a species of Blaniulus from amber, and probably the *Julopsis cretacea* of Heer, from the Cretaceous deposits of Greenland, is to be referred to this family.

Polyxenidæ.—Polyxenus is represented by five species in amber, of which Koch and Berendt describe and figure two and the others are briefly characterized by Menge. Besides these, Menge describes an amber genus, Lophonotus,[1] in which the sixth antennal joint is the largest, the terminal joint very short and cylindrical, furnished above with four little teeth. A single species is known, *Phryssonotus hystrix* Menge sp.

[1] This name had been used earlier for other insects, and may be replaced by Phryssonotus.

ARACHNIDA.

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CHARACTERISTICS AND GEOLOGICAL HISTORY.

The Arachnida are articulated animals in which the body is, as a rule, divided into two great masses, a cephalothorax and an abdomen. The cephalothorax is furnished with four pairs of articulated (normally, seven-jointed) legs, and in advance of them (1) a pair of jointed appendages or palpi which in some bear chelæ or other modified structures at the extremity and generally are looked upon as the homologues of some part of the jaws of insects; and (2) a pair of two-jointed mandibles or cheliceres, sometimes developed as a sucking organ, and considered

by many as equivalent to the otherwise absent antennæ of true insects. The eyes are always simple and situated on the summit of the front portion of the cephalothorax. The abdomen is in some cases of a softer integument than the cephalothorax, in which its annulated character is disguised. It bears no legs, but sometimes has special jointed appendages either at the base, as in scorpions, or at the extremity, as in spiders. With slight exceptions arachnids undergo no metamorphosis after leaving the egg, the repeated sloughings of the integument being unaccompanied by structural changes.

The geological history of Arachnida, as known at the present time, presents some points of interest. Only a portion of the great groups into which the order is divisible are represented in the older rocks, and these, which are not confined to the lower types, attain a degree of perfection and a diversity of structure inconsistent with a belief in our having reached the primordial forms of this phylum in our retrograde search.

When, in 1858, Bronn published his prize essay on the distribution of fossils, only two species of Pretertiary Arachnida were known as such, one from the Carboniferous and one from the Jurassic formation, and the knowledge of Tertiary forms was confined entirely to the then recently published work of Koch and Berendt on the species from amber. Since then Menge has increased somewhat our knowledge of the amber fauna, and it includes to-day nine-tenths or more of the known Tertiary species. But it is only within the last fifteen years that our knowledge of Pretertiary Arachnida has been extended beyond the description of two or three species. The number is still exceedingly few—between 20 and 30 species—but it is being constantly extended, and the abundance of Arthropoda brought to light in recent years in the Carboniferous deposits of Allier, Bohemia, Scotland, and Illinois, leads us to expect an early and considerable extension of the list. This expectation is strengthened by Lindström's, Hunter's, and Whitfield's discoveries of scorpions in the Upper Silurian rocks of Gotland, Scotland, and New York.

The forms that have been found fossil in the earlier formations prove, as might be expected, to belong mostly to those having a dense integument, and in the two species believed to be true Araneæ the abdomen was probably provided with more or less densely chitinous dorsal plates. With these two exceptions and a single genus of Pedipalpi, all the Paleozoic Arachnida (only a single Mesozoic form is known) belong either to the Scorpiones or to a peculiar group, the Anthracomarti. This group is not found later, and the single known species of Mesozoic Arachnida[1] is a true Aranea. The paucity of remains of Arachnida in Mesozoic strata is somewhat remarkable. Besides the

[1] Palpipes or Phalangites, believed even by Thorell to be an arachnid, has been shown by Seebach to be a stomatopodous crustacean.

species mentioned above, only one other has been indicated, a species supposed to belong to the Araneæ, from the English Lias.

Thanks to the amber deposits of Prussia, we know far more about the Tertiary history of Arachnida than would be possible if our sole reliance were on the rocks, the latter furnishing us with only about double the number of those occurring in Pretertiary deposits. In the amber alone occur all the suborders of Arachnida (excepting the Pedipalpi and the already extinct Anthracomarti), as well as all the families of Araneæ, excepting one peculiar to the Jura; but in the Tertiary rocks neither Chelonethi, Scorpiones, nor Opiliones has been recognized; of the Pedipalpi, a single species is referred to by Serres from the marls of Aix, but too obscurely to take account of it.

Examining the Araneæ alone, which are far better represented in the Tertiaries than are the other suborders, we find a very large number of extinct genera. In all, 71 are now known, 66 from Europe and 13 from America, 8 being common to both. Of these 37 are accounted extinct (35 from Europe and 2 from America), and none of these have been found on both continents.

In the stratified Tertiary deposits the same families of Araneæ are in every instance found in both Europe and America, excepting the Dysderides, which family has a single representative in America and none in Europe. It also appears that just those families which are represented abundantly in amber are also found to some extent in the American Tertiary fauna and (excepting, as before, the Dysderides) in the European rocks.

It is only in the rocks of the temperate regions of Europe and North America that any Arachnida have been found in a fossil state, and these, so far as the indications have any meaning, invariably point, whether in Carboniferous or in Tertiary deposits, to a warmer climate than now obtains in the localities where they occur. This becomes more marked when we reach the Tertiary rocks and can compare the types more closely with existing forms, a number of the genera to which, for instance, the amber spiders belong being now exclusively tropical.

The following table gives a general systematic view of the distribution of Arachnida in the different geological formations since their first appearance in the Upper Silurian.

Geological distribution of Arachnida.[1]

Groups.	Paleozoic.				Mesozoic.				Cenozoic.				
	Silurian.	Devonian.	Carboniferous.	Dyas.	Trias.	Lias.	Jura.	Cretaceous.	Oligocene. Europe.	Oligocene. America.	Miocene.	Pliocene.	Modern period.
Acari	....	....	....	....	....	....	....	....	33	1	2	....	....
Chelonethi	....	....	....	....	....	....	....	....	9	....	....	....	....
Anthracomarti	....	....	16	....	....	....	....	....	....	....	....	....	0
Pedipalpi	....	....	2	....	....	....	....	....	....	....	....	....	....
Scorpiones	3	....	8	....	....	....	....	....	1	....	....	....	....
Opiliones	....	....	....	....	....	....	....	....	13	....	....	....	....
Araneæ:													
Saltigradæ	....	....	....	....	....	....	....	....	15	3	....	....	....
Citigradæ	....	....	....	....	....	....	....	....	1	....	....	....	....
Laterigradæ	....	....	....	....	....	....	....	....	22	3	4	....	....
Territelariæ	....	....	2	....	....	....	....	....	1	....	....	....	....
Tubitelariæ	....	....	....	....	....	....	1	....	72	8	3	....	....
Retitelariæ	....	....	....	....	....	....	....	....	54	3	5	....	....
Orbitelariæ	....	....	....	....	....	....	....	....	17	12	3	....	....

[1] The figures represent the number of species.

1. Order ACARI Leach.

Body compact, robust, the cephalothorax and unsegmented abdomen being united in one mass. Mouth-parts usually produced into the form of a rostrum.

All the principal families are represented in the Tertiaries, our knowledge of them coming mainly from amber. With a single exception, they have all been referred to existing genera. None have been reported from older rocks.

Sarcoptidæ.—A species of Acarus has been found in amber and one is referred to by Heer as occurring at Oeningen.

Oribatidæ.—A species of Oribates and four of Nothrus occur in amber.

Ixodidæ.—A single species of tick found in the Green River beds of Wyoming is probably to be referred to this group.

Gamasidæ.—One species of Sejus is figured by Koch and Berendt from amber.

Hydrachnidæ.—Heyden figures a species of Limnochares from the brown coal of Rott.

Bdellidæ.—As we reach the higher Acari their fossil representatives become more numerous. Four species of Bdella and one of Cheyletus have been found in amber.

Trombididæ.—This family of Acari is by far the best represented in a fossil state, more than twice as many species having been recovered

from amber as all the other families together have furnished, but none have been found in the stratified rocks. Five species of Trombidium, eight of Rhyncholophus, three of Actineda, four of Erythæus, two of Tetranychus, and one of Penthaleus have been described and in part figured by Menge and Koch, besides one of the only genus not now living, Arytæna Menge, having the aspect of a Trogulus.

2. Order **CHELONETHI** Thorell (Pseudoscorpiones Latreille).

Body strongly depressed, the sides of the body showing no division between cephalothorax and abdomen, the latter composed of ten or eleven segments. Palpi long and stoutly chelate.

Hope catalogues a species of Chelifer from the Tertiary deposits of Aix, but the only forms which have been described are those from amber, which have been carefully studied by Menge and figured in his paper on Chernetidæ. He finds five species of Chelifer and one each of Chernes, Cheiridium, and Chthonius, all of the genera still existing. Some of the species, however, differ so much from living forms that Menge previously endeavored to establish two distinct genera for them. A species of Carboniferous arachnid, long supposed to belong in this group, has recently been shown by Fritsch to be an immature and imperfect scorpion. (See, also, page 95.)

3. Order **ANTHRACOMARTI** Karsch.

Body somewhat depressed, the cephalothorax and abdomen distinctly separable. Cephalothorax usually made up in large part of more or less wedge-shaped pedigerous segments, the arrangement of which corresponds to that of the coxæ. Abdomen forming a single mass and composed of from four to nine distinct joints. Palpi not much longer than the legs and simply terminated.

This group, the only extinct order of Arachnida, was established by Karsch for some interesting Carboniferous forms of somewhat obscure relations allied to the Phrynidæ and Phalangidæ, but very distinct from either of them. Their position seems to be between the Chelonethi and the Pedipalpi, to the latter of which they bear perhaps the closest relations. The Anthracomarti were the most varied in structure and, with the possible exception of the scorpions, the most abundant in species of the Carboniferous Arachnida, and being unknown after that period they may be considered the most characteristic of Paleozoic Arachnida. The forms hitherto known may be grouped in four families.

1. Family **Arthrolycosidæ** Harger.

Cephalothorax orbicular. Coxæ radiating from a central pit. Abdomen oval, narrower at base than the cephalothorax, with no longitud-

inal sculpturing, and smooth. Segments seven in number, undoubtedly all visible below. No abdominal appendages.

Arthrolycosa Harg. Cephalothorax twice as large as the abdomen. Founded upon *A. antiqua* Harger, from the Carboniferous iron-stone nodules of Mazon Creek, Ill.

Rakovnicia Kušt. Cephalothorax smaller than the abdomen. *R. antiqua* Kušta from the coal measures of Bohemia.

2. Family **Poliocheridæ** Scudder.

Cephalothorax quadrate, not much smaller than the abdomen. Coxæ radiating apparently from a median line. Abdomen rounded, of equal breadth with the cephalothorax, composed of only four segments, of which the basal is very short and the others of equal length. No abdominal appendages.

Poliochera Scudd. One species, *P. punctulata* Scudder, from Mazon Creek, Ill.

3. Family **Architarboidæ** Karsch.

Cephalothorax variable in form, at least half as large as the abdomen; coxæ radiating from a central pit, a median line, or from a broad triangular space, its base on the abdominal margin. Abdomen orbicular or oval, broad at base, with a lateral ridge on each side converging toward the anus; the surface moderately smooth; segments seven to nine in number, visible below, though the basal ones often extremely shortened in the middle. No abdominal appendages.

Geraphrynus Scudd. Cephalothorax fusiform, angulate in front, nearly as large as the abdomen; the coxæ radiating from a median line. Sides of the body scarcely showing any constriction between the cephalothorax and the abdomen. Abdomen subfusiform, composed of nine segments, with a large basal, triangular, post-thoracic plate crowding the middle of the shorter basal segments out of place on the dorsal surface. *G. carbonarius* Scudd., from the Carboniferous nodules of Mazon Creek, Ill.

Architarbus Scudd. Cephalothorax orbicular, broadly rounded in front, much smaller than the abdomen; the coxæ radiating from a central pit. Sides of the body scarcely showing any constriction between the cephalothorax and the abdomen; the latter oval, composed of nine segments, of which those on the basal half are very much shorter than the others. *A. subovalis* Woodw., from the Coal Measures of Lancashire, Eng., has the piece exposed between the posterior coxæ more than twice as broad as long. (Probably *Curculioides Ansticii* Buckl. belongs here.) In *A. rotundatus* Scudd., from Mazon Creek, Ill., this piece is triangular, of equal length and breadth, the post-thoracic plate large, greatly distorting the basal segments of the abdomen. Roemer mentions a third species (*A. silesiacus*), from the Carboniferous deposits of Glatz.

Anthracomartus Karsch. Cephalothorax quadrate, the front square, or scarcely convex, about half the size of the abdomen; the coxæ laterally affixed, radiating from a broad triangular sternal plate, the base of which forms the posterior margin. Sides of the body showing a distinct though slight constriction between the cephalothorax and the abdomen by the more convex sides of the latter. Abdomen orbicular, a little longer than broad, composed of seven segments of similar length. Four European species are known, from the Carboniferous deposits of Silesia and Bohemia, and two American, from those of Illinois. (Probably *Termes Hageni* Gold. (Palæontogr., Band IV., Pl. 6., Fig. 8) and *Libellula carbonaria* Scudd. (Proc. Amer. Assoc., Vol. XXIV, B. 110, Fig. 1), both represented by imperfect bodies only, belong in this neighborhood.)

4. Family **Eophrynoidæ** Karsch.

Cephalothorax quadrate or triangular, less than one-third the size of the abdomen, broken dorsally into many distinct plates. Coxæ radiating from a sunken median furrow. Abdomen ovate or orbicular, much broader than the cephalothorax, and separated from it by a distinct lateral constriction, composed of nine or ten segments, of which the penultimate and antepenultimate bear lateral terminal spines.

Kreischeria Gein. Cephalothorax subquadrate, narrowing strongly in front, the dorsal surface with three large median plates, one in front and two behind, and on each side three smaller lateral plates. Dorsum of abdomen broken by oblique sutures into a median and a lateral field. *Kreischeria Weidei* Gein., from the Coal Measures of Zwickau, Saxony, is a gigantic species, and the largest known fossil arachnid, excepting some scorpions.

Eophrynus Woodw. Cephalothorax triangular, pointed in front, its dorsal surface tumid, completely broken into great tuberculate bosses arranged in a lateral row down either side and a median row separating into two at the posterior margin. Dorsal surface of abdomen tuberculate, with two lateral rows of large rounded tubercles and a median row of large stellate tubercles. The genus was founded on *E. Prestvicii*, from the iron-stone nodules of the Coalbrookdale and Dudley Coal Measures in England. This species was formerly taken by Buckland for a beetle, and was figured by him in his Geology and Mineralogy as *Curculioides Prestvicii*. Since then Stur has described a second species from Ostrau, in Moravia, under the name of *E. Salmi*.

4. Order **PEDIPALPI** Latreille.

Body depressed, the cephalothorax and abdomen distinctly separate. Cephalothorax compact, but sometimes broken into two parts; the legs, especially the front pair, very long. Abdomen composed of an abdomen proper of more than seven joints, to which is generally appended a

post-abdomen, formed of a few small joints followed by a generally articulated seta. Palpi highly developed, spinous, apically chelate.

Serres mentions a species of Phrynus from the Tertiary deposits of Aix, excepting which the only known fossil is a Thelyphonus-like arachnid from the Carboniferous deposits of Bohemia and America, belonging to a family distinct from those now existing.

Family **Geralinuridæ** Scudder.

Cephalothorax divided into two masses: the hinder much the smaller, short, and transverse, and carrying only the hindmost legs; the front portion large, tapering anteriorly, and furnished with long and slender cheliceres. Abdomen subfusiform. While most nearly related to the Thelyphonidæ, this family, by the division of the cephalothorax, shows more affinity to the Nyctalopidæ.

Geralinura Scudd. Cephalothorax ovate, the front rounded, one-third as broad as hinder portion. Palpi large and robust, with interior spines. First two pairs of legs slender, the hinder stout and broad. Abdomen composed of nine joints, the basal three rather short, the others subequal and longer; post-abdomen much as in Thelyphonus. *G. carbonaria* Scudd., in iron-stone nodules from Mazon Creek; *G. bohemica* Kušt. sp., from Rakonitz, Bohemia.

5. Order **SCORPIONES** Thorell.

Body depressed; the cephalothorax and abdomen distinctly separated, as in the last group; the latter composed (1) of seven joints, forming the abdomen proper, at the base of which beneath is a pair of pectinate appendages, and (2) of six slender joints, forming the tail or post-abdomen, of which the last joint is vesicular and developed as a sting. Palpi large and chelate.

This is, perhaps, the most sharply defined of all the orders of Arachnida, and is a group of the greatest antiquity, several species having been found in the Upper Silurian rocks of Sweden, Scotland, and New York, while the Carboniferous beds have yielded a considerable variety of forms in both the Old and New World, all of which seem, at least as far as any characteristics have been noted, to enter as completely into the order as if they were living to-day. The Paleozoic forms represent, however, a distinct and extinct suborder, in which those from the European Silurian beds are to be distinguished as a separate group from the Carboniferous types, among the latter of which, however, the single known American scorpion must be placed. The Silurian species are very recent discoveries, the characteristics of which have been made known to us by Thorell, Peach, and Whitfield.

1. Suborder ANTHRACOSCORPII Thorell.

Anterior margin of cephalothorax generally produced centrally. Dorsal eye tubercle situated not far from or at the anterior margin, in front of or between the lateral eyes; the dorsal eyes when present generally rather large. Bases of the second pair of legs separated from each other by a pair of median plates. Rachis of comb formed of four or more plates.

This suborder includes all and only the Paleozoic forms and contains two families, the first embracing the species from the European Silurian, the second the American Silurian scorpion and the Carboniferous species of both continents.

1. Family **Palæophonoidæ** Thorell.

Anterior margin of cephalothorax very broadly emarginate. Eye tubercle small, situated mesially, near but not on the front margin of the cephalothorax. Sternum large and pentagonal, bounded anteriorly by the third pair of coxæ. Movable finger of mandibles apparently armed with a single row of teeth. Hands stout. Legs short, gradually tapering; the tibial and femoral joints scarcely longer than broad; the last tarsal joint conical, pointed, without claws or with a single minute apical claw.

This group contains the single genus Palæophonus, if the species almost simultaneously discovered in the Ludlow beds of Gotland and Scotland in the summer of 1884 are, as is probably the case, not generically distinct. It is remarkable for the tapering form of the legs. The Gotland specimen, *Palæophonus nuncius* Thorell and Lindström, has been carefully studied by Thorell, and is certainly remarkable for the excessively heavy joints of the palpi before the chelate tip, as well as for the brevity of the legs and their form, since all of them are stout and the last three joints taper regularly to a single, pointed, spine-like claw. Only a preliminary notice of the Scottish species has yet been given by Peach, according to whom the sternum shows a large pentagonal plate, against which the wedge-shaped coxæ of the last pair of legs abut, while the coxæ of the third pair bound the pentagonal plate along its upper margins and meet in the mid-line of the body, where they are firmly united.

2. Family **Eoscorpioidæ** Scudder.

Anterior margin of cephalothorax roundly or angularly produced in the middle. Sternum compound, bounded anteriorly by the second pair of coxæ. Hands slender. Legs comparatively long, of nearly uniform breadth; the tibial and femoral joints much longer than broad; the last tarsal joint cylindrical, blunt at tip, and armed with a pair of claws.

1. Subfamily *Proscorpionini* Scudder.

Dorsal eye tubercle of moderate size, situated mesially on the front margin of the cephalothorax; the dorsal eyes small; lateral eyes in two rows on antero-lateral border.

Here belongs the single species *Proscorpius Osborni* Whitfield, from the Silurian (extreme base of Helderberg group) of New York, discovered in the winter of 1882, but only just made known; the horizon from which it comes is probably somewhat lower than that at which Palæophonus has been found, but the species agree more closely with the later Carboniferous types.

2. Subfamily *Eoscorpionini* Scudder.

Dorsal eye tubercle small, situated mesially near but not on the front margin of the cephalothorax; the dorsal eyes minute; lateral eyes in two rows on antero-lateral border. Rachis of combs composed of numerous lamellæ.

Eoscorpius Meek and Worth. No intermediate lamellæ in the combs. Two species in the Carboniferous beds of Illinois. Mazonia Meek and Worth. is probably synonymous.

Centromachus Thorell. Combs provided with numerous intermediate lamellæ. Five species from the Carboniferous beds of Scotland and England.

3. Subfamily *Cyclophthalmini* Thorell.

Dorsal eye tubercle very large, occupying nearly half the cephalothorax centrally in front; the dorsal eyes very large; lateral eyes forming a semicircular row behind and beside the latter. Rachis of the combs formed of few plates; no intermediate lamellæ.

Cyclophthalmus Corda. Three species from the Carboniferous of Bohemia.

Other species of this family are indicated from Bohemia, Illinois, and Nova Scotia. The problematical genus Glyptoscorpius Peach is referred by him to the Eurypteridæ.

2. Suborder NEOSCORPII Thorell.

Anterior margin of cephalothorax truncate or emarginate in the middle. Dorsal eye tubercle generally far removed from the anterior margin, behind the lateral eyes; the dorsal eyes themselves, when present, comparatively small. Sternum bounded anteriorly by the coxæ of the second pair of legs; bases of these legs attingent at the middle line. Rachis of combs formed of no more than three plates.

3. Family **Buthoidæ** Simon.

Sternum narrowing forward, subtriangular. Intermediate lamellæ of the pectoral combs rather few in number, most of them angular and

larger than the fulcra, and forming only one series. Three principal lateral eyes and 2–0 accessory eyes on each side of the cephalothorax. *Tityus eogenus* Menge, from amber, is the only Tertiary species tolerably known.

6. Order **OPILIONES** Sundevall.

Body compact, depressed; the cephalothorax and abdomen united in a single mass, the latter composed probably of eight segments, of which the five basal joints are so obscurely marked as to form apparently a single mass. Palpi filiform, apically achelate. Legs long, terminated by a single claw.

This order is represented only in Cenozoic times and is indeed known in a fossil state only in amber. Most of the species belong to the family *Phalangioidæ*, which is represented by a single species each, of the genera Acantholophus, Phalangium, Liobunum, Platybunus, and Cheiromachus, and by three which have been referred to Opilio. The *Nemastomoidæ* are represented by the genus Nemastoma (4 sp.), and the *Gonyleptidæ* by Gonyleptes (1 sp.).

7. Order **ARANEÆ** Sundevall.

Body robust, composed of two well-separated masses; the abdomen being petiolated with, at the most, but faint marks of segmentation and furnished apically with spinnerets. Palpi subfiliform, simple, excepting that the last joint of the male possesses peculiar organs subservient to copulation, never chelate.

1. Suborder SALTIGRADÆ Latreille.

A dozen species of *Attoidæ* are known from amber, belonging to the genera Propetes and Gorgopis, besides species of Steneattus and Euophrys. In addition to these we have three species of Parattus from the Tertiary beds of Colorado, an extinct genus interesting from its affinity to Gorgopis, and the excellently preserved *Attoides eresiformis* from the gypsum of Aix. Of the *Eresoidæ*, two species of Eresus are found in amber.

2. Suborder CITIGRADÆ Latreille.

Represented by the *Lycosoidæ*, in which Menge has founded the genus Linoptes on a single amber species.

3. Suborder LATERIGRADÆ Latreille.

Koch establishes the family *Archæoidæ* upon the single amber genus Archæa, with half a dozen species, remarkable for the globular elevation of the cephalic portion of the cephalothorax, the long mandibles, and the unusually small and slender palpi. He believed that it differed totally from all other spiders, but both Menge and Thorell refer it to the position here assigned. The *Thomisinæ* are richly represented in the

Tertiaries, especially in amber, ten genera being known, of which Clythia and Syphax, with five species each, and one or two others are known only from amber. The species from the rocks have all been referred to Thomisus and Xysticus, existing genera, and have been found at Oeningen, Rott, and Florissant (Colo.).

4. Suborder TERRITELARIÆ Thorell.

Clestes, an extinct genus of *Theraphosoidæ*, is represented by a single species in amber; but the most important fact is that Thorell refers to the existing family *Liphistioidæ* that interesting Carboniferous form from Silesia described under the name of *Protolycosa anthracophila*, on account of the brevity of the first pair of legs and the density and segmentation of the dorsal integument of the abdomen. Thorell also calls attention to the unusually short second joint of the palpi and to the spines on the abdomen as points which might justify the establishment of a distinct family for it. Though less well preserved, Fritsch's *Palaranea borassifolia*, from the Coal Measures of Bohemia, would seem to fall in this same group. No other Carboniferous Araneæ are known in this group, and no Mesozoic or Tertiary species are known, though a single genus exists at the present day in the East Indies.

5. Suborder TUBITELARIÆ Thorell.

The families which are represented in the Tertiary deposits of Europe and America are the ones most abundant in the present epoch, and the suborder itself includes more than a third of the Tertiary Araneæ. The fossil *Dysderides* of Europe (16 species) are all from amber and include eight species of Segestria, into which the single species from the volcanic strata of Colorado also falls. Therea is an extinct genus peculiar to amber. The *Drassides* are very abundant in the European amber, and the American fauna shows four species of Clubiona and one of Aryphæna, both living genera represented in amber, with Clubiona (which has no less than eight amber species) also at Oeningen; but besides these there are half a dozen extinct genera found in amber, mostly with only one or two species each. Six genera of *Agalenidæ* are found in the European Tertiaries, half of them in amber, the other half at Rott and Oeningen. The amber genera are all extant, but one of the species from Rott—*Argyroneta antiqua* Heyd.—belongs, according to Thorell, to an extinct type (Elvina), in which the palpi are evidently thicker than the legs. Bertkau, however, who has since studied it carefully, retains it in Argyroneta. Two species from Colorado belong to Tetanœca, a European genus, not found fossil in the Old World, but allied to Amaurobius, one of the genera represented by three species in amber. Besides these, Hasseltides, a Mesozoic genus from Solenhofen, is referred to this family by Weyenbergh. The *Hersilioidæ* are represented in amber by two species of Hersilia, a subtropical genus, not now

existing in Europe, and a species of Gerdia, a remarkable generic form peculiar to amber, in which the head is raised to a high vertical boss, the tarsi are two-jointed, and the spinnerets are very long and three-jointed. And, finally, Thorell establishes a new family *Mizalioidæ* for the curious genus Mizalia, of which four species are known in amber, in which the cephalothorax is produced like a blunt snout in front of the eyes, the legs and palpi are stout, and the intermediate spinnerets are more than double the length of the inferior.

6. Suborder RETITELARIÆ Thorell.

Next to the Tubitelariæ in importance, especially so far as the amber fauna is concerned, comes this suborder. The *Scytodoidæ* contain a species of Pholcus and another of the extinct genus Phalangopus, but the mass of this group belong to the *Theridioidæ*, a family more abundant than any other among the Araneæ in Tertiary deposits, more than a fourth of the European species belonging here, with fourteen genera. America, whose stratified deposits are generally richer than the similar beds of Europe, is in this instance poorer, but possesses a single species of Linyphia and two of Theridium, besides some egg-cocoons apparently made by a spider of this group. Theridium is one of the very richest of the amber genera, having sixteen species, while three others are described from Oeningen and Aix. Linyphia has three species in amber and two at Rott; Erigone, one each in amber and at Rott. Schellenbergia is an extinct genus founded by Heer for a spider found at Oeningen. Among the more prolific genera found in amber, and not named above, are Ero, with seven species; Walckenaeria and Zilla, with five each; and Thyelia, a form peculiar to amber, with no less than ten species. Other extinct genera are Flegia, Corynitis, Anandrus, Clya, and probably Dielacata, most of which are known by a single species each.

7. Suborder ORBITELARIÆ Perty.

In this group, containing the single family *Epeiroidæ*, there is a curious disparity of representation between the European and the American Tertiaries, 8 per cent. of the European Tertiary spiders belonging to this group, while no less than 44 per cent. of the American species fall here, and no other group shows in America so many novelties. Among these are single species of the genera Nephila and Tetragnatha, not found fossil in Europe, and four species of an extinct type, Tethnæus, a genus of spiders of compact form, with short and stout legs, of not very unequal length, and in which the two front pairs are unusually heavy. They all come from the beds at Florissant, Colo. Six species referred to Epeira also come from Colorado, two from Rott, one from Oeningen, and two from amber. All the other Tertiary Epeiroidæ come from amber and include two or more species each of Græa, Antopia, Siga, and Androgeus, all extinct types, besides a few others.

INSECTA.

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(See, also, pp. 36, 46, 51, 58, 65, 85, 94, and 96.)

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CHARACTERISTICS AND DEVELOPMENT.

Hexapods, or true insects, are articulated animals in which the body of the adult is divided typically into three principal regions: head, thorax, and abdomen. The head is composed of several consolidated segments (generally looked upon as four in number) and bears above a pair of antennæ, serving as sense and tactile organs, and below three pairs of jointed appendages, serving under various modifications as mouth-parts. These are designated from the front backward as mandibles, maxillæ, and labium. The opposing basal parts of the last are more or less closely united to form a lower lip, and upon the opposite front or upper side of the mouth a hinged and undivided, though sometimes partially cleft, plate is found, called the labrum or upper lip; the maxillæ and labium may have jointed appendages or prolongations, the modifications of which, profoundly affecting the modes of life and nourishment of insects, characterize the different primary groups and are undoubtedly of great antiquity. A pair of compound eyes is found on the sides of the head and ocelli are sometimes added in front.

The thorax is composed of three segments, each of which bears a pair of legs and each of the hinder two a pair of wings, which, especially the posterior, are occasionally aborted. Each of these segments is again divided by sutures into several plates, bearing definite and similar relations on each segment; they are situated above, on the sides, and below, and are distinguished respectively as nota, pleura, and sterna, the pleura being again subdivided into an anterior episternal and a posterior epimeral piece. Between nota and pleura the wings,

and between pleura and sterna the legs, are inserted. The latter consist of five parts: coxa, trochanter, femur, tibia, and tarsus, the last rarely simple, generally five-jointed, the final joint armed with a pair of claws and sometimes with fleshy pads or lobes.

The wings, the most characteristic feature of the class, are composed of a thin membrane, stretched, like a flattened bladder, upon a framework of veins, the arrangement and disposition of which are definite and of the utmost importance for paleontology, as these are the parts, particularly in the older insects, which are more often preserved, and frequently serve as the sole clew to relationship. These veins or nervures are hollow, ramificating, and more or less anastomosing tubes, containing tracheæ and the fluids of the body. The principal veins are six in number, arising in sets of three, from two distinct roots, the marginal, mediastinal, and scapular veins being articulated anteriorly, the externomedian, internomedian, and internal veins posteriorly; by a basal bend in the course, however, the scapular or the externomedian vein may, as it were, select its articulation at will. The definite arrangement of these veins and their off-shoots has frequently served, in all orders of insects, as a base for generic, and occasionally for family, distinctions, but its wider use has been much hampered by a very variable nomenclature of the veins in different orders, which has taken no note of their homologies.

The different orders differ also in the general texture of the front wings and their relative size, as compared to the hind wings, the former being sometimes of a much denser consistency than the latter and serving as a protective covering to them, which then become the principal organs of flight, and are often folded in various ways for concealment beneath the front wings.

The abdomen is generally composed of nine or ten segments, to each of the last two or three of which one, two, or even three pairs of appendages may be attached, often closely connected with the reproductive function as ovipositors or clasping organs, but also as stings and jointed filaments. In ovipositors and stings the appendages of opposite sides or of different segments, or of both, are often combined to form compound structures; in the other cases the appendages are usually simple and distinct.

Respiration is effected by means of tracheæ filled with air through lateral openings or stigmata on the sides of most of the thoracic and abdominal segments, to the number usually of nine or ten on each side of the body; these are connected by main trunks extending along each side of the body and themselves divide into numerous ramifications, which permit the aëration of every part of the body.

Growth is secured through repeated sloughings of the chitinous integument of the body, accompanied by very varied and remarkable metamorphoses. In some types the young as hatched from the egg very closely resemble the parent insect, except in the absence of wings, and when the parent is itself apterous the resemblance is still more evident.

In others, on the contrary, the difference is very important, and to bridge over the wide distinction a quiescent period intervenes between the initial and the final period, resulting in a threefold life condition, the first stage being known as the larva, caterpillar, or maggot, the second as the pupa or chrysalis, and the final as the imago or perfect stage. Such a metamorphosis is designated as complete. The insects with incomplete metamorphosis, on the other hand, do not need such a quiescent stage, the ordinary ecdysis sufficing for all the changes required for the assumption of maturity.

As the conditions under which insects are preserved in the rocks do not admit of any study of their internal structure, this side of their organization need not here be touched upon. Yet it is remarkable to find how perfectly external parts and organs of the utmost delicacy have been preserved not only in amber, which has revealed and is yet to reveal the most important and exact data regarding insect life in the early Tertiaries, but even in the rocks themselves, where the most delicate hairs, antennal outgrowths, the appendages of the feet, and the microscopic facets of the compound eye are exactly preserved. Especially is this true of the neuration of the wings in every type and in all time, thus preserving for us the most precious data for the rehabilitation of the insect life of different epochs.

As the classification here followed is intimately connected with the historical development of the different ordinal types, its exposition is postponed to the close, where the subject will be discussed in connection with the geological distribution of insects.

A.—PALÆODICTYOPTERA Goldenberg.

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Body generally elongated, mouth-parts variously developed; antennæ filiform. Thoracic joints subequally developed; legs moderately long. Mesothoracic and metathoracic wings closely similar, equally membranous; the six principal veins always developed, the marginal simple and

forming the costal border, the mediastinal generally simple or with superior branches only; the other veins usually dichotomize; stout and well-defined cross-veins rare; membrane generally reticulate. Wings in repose lying on the abdomen, the anal area of the hind wings, though usually of great distal extension, never plaited, though sometimes broadly folded. Abdomen usually long and slender, the last joint often furnished with simple articulated appendages.

The insects composing this order were in fact ordinally undifferentiated Hexapoda, and comprised all the insects of Paleozoic time, together with a few later ones. They may be divided by their general facies and by their evident relationship to succeeding types into four sections, Orthopteroidea, Neuropteroidea, Hemipteroidea, and Coleopteroidea.

1. Section **ORTHOPTEROIDEA** Scudder.

1. Family **Palæoblattariæ** Scudder.

Ancient cockroaches in which the externomedian vein of the front wing is completely developed, dividing in the outer half of the wing, its branches generally occupying the apical margin; anal branches terminating on the inner margin of the wing.

1. Subfamily *Mylacridæ* Scudder.

Branches of the mediastinal vein arranged in a radiate manner, mostly springing from a common point at the base of the wing; mediastinal area subtriangular, uniformly tapering apically. (North America.)

Mylacris Scudd. Wings broad. Mediastinal and scapular areas together occupying less than half the wing. Scapular area larger than the mediastinal. Carboniferous, ten species. Cape Breton, Nova Scotia; Pennsylvania; Illinois.

Promylacris Scudd. Body much arched. Wings broad. Mediastinal and scapular areas together not occupying more than a third of the wing. Scapular area smaller than the mediastinal, the scapular running obliquely to the costal margin. Carboniferous. *P. ovale* Scudd. Mazon Creek, Ill.

Paromylacris Scudd. Body much arched. Pronotal shield more than twice as broad as long. Wings extremely broad. Mediastinal area large and extended and, with the scapular vein, occupying half the wing. Externomedian area expanding apically. Carboniferous. *P. rotundum* Scudd. Mazon Creek, Ill.

Lithomylacris Scudd. Wings slender. Mediastinal and scapular areas together occupying more than half the wing; externomedian area small and compressed, scarcely expanding apically. Carboniferous. Four species. Pennsylvania and Illinois.

Necymylacris Scudd. Some of the apical branches of the mediastinal vein arising beyond the base of the wing and scarcely partaking of the

radiate arrangement of the others. Carboniferous. Two species. Pennsylvania.

2. Subfamily *Blattinariæ* Scudder.

Branches of the mediastinal vein arising at regular intervals from a principal stem; mediastinal area generally band-shaped. (Europe and North America.)

Etoblattina Scudd. Mediastinal area comparatively short; scapular vein not reaching tip of wing and, with the externomedian, which is comparatively large, occupying less than half the wing; internomedian vein comparatively long. Carboniferous and Trias. About 25 species. Europe and North America.

Spiloblattina Scudd. Mediastinal area comparatively short; scapular area just reaching the tip of the wing and, with the externomedian, occupying about half its area; externomedian and internomedian veins diverging around a median stigma. Trias. Four species. Colorado.

Archimylacris Scudd. Mediastinal area comparatively short; scapular terminating below the tip and, with the externomedian, which is comparatively small, occupying less than half the wing; internomedian vein comparatively long. Carboniferous. Three species. Nova Scotia, Pennsylvania, and Illinois.

Anthracoblattina Scudd. Mediastinal area comparatively long; scapular and externomedian areas together occupying less than half the wing; the branches of the former superior, of the latter inferior; internomedian vein comparatively long. Carboniferous. Twelve species. European.

Gerablattina Scudd. Mediastinal area comparatively long; scapular and externomedian areas together occupying less than half the wing, the branches of both superior; internomedian vein comparatively long. Carboniferous. Thirteen species. Europe and North America.

Hermatoblattina Scudd. Mediastinal area comparatively long; scapular and externomedian areas together occupying less than half the wing, the branches of the former inferior; internomedian vein comparatively long. Carboniferous. Two species. Germany.

Progonoblattina Scudd. Principal veins closely crowded in the basal half of the wing; scapular area not reaching apex, but with the externomedian area occupying more than half the wing, the branches of the latter inferior; internomedian vein comparatively short. Carboniferous. Two species. Germany and Switzerland.

Oryctoblattina Scudd. Principal veins widely separated at base: scapular area surpassing apex and, with externomedian, occupying more than half the wing, the branches of latter inferior; internomedian vein comparatively short. Carboniferous. Three species. Germany and Illinois.

Petrablattina Scudd. Scapular and externomedian areas together covering more than half the wing, the externomedian vein directed

toward and terminating near the middle of the inner border of the wing, its branches superior; internomedian vein very short. Carboniferous and Trias. Four species. Germany, Nova Scotia, and Colorado.

Poroblattina Scudd. Scapular and externomedian areas together covering more than half the wing; the externomedian vein directed toward the outer half of lower border, its branches superior; internomedian vein moderately long. Trias. Two species. Colorado.

2. Family **Protophasmida** Brongniart.

Ancient walking-sticks, in which the front wings were diaphanous and as fully developed as the hind wings and both were similar in form and general neuration to those of other Palæodictyoptera, being long and usually slender, with very simple branched veins.

Titanophasma Brongn. Wings very large, moderately slender; the neuration moderately abundant; scapular vein beginning to branch in the middle of the basal half of the wing. Carboniferous. Three species. Commentry, France; Saarbrück basin; Pittston, Pa.

Litoneura Scudd. Wings of moderate size, the veins comparatively few, distant, and simple; scapular vein first branching beyond the middle of the wing and usually far from the first forking of the externomedian vein, its branches arising from the main stem. Carboniferous. Three species. Saarbrück basin.

Dictyoneura Goldenb. Wings of rather small size, with sparse neuration, the scapular nervules springing from a principal branch, which arises before, generally far before, the middle of the wing, the nervules only at some distance beyond the same; internomedian vein simple. Carboniferous. Four species. Saarbrück basin.

Polioptenus Scudd. Wings similar to the last, the principal scapular branch arising only just before the middle; internomedian vein branched. Carboniferous. *P. elegans* Goldenb. sp. Saarbrück basin.

Archæoptilus Scudd. Wings of huge size, the neuration tolerably abundant, the main scapular branch arising about the middle of the wing and having numerous off shoots; externomedian vein branching abundantly in the middle of the wing. Carboniferous. *A. ingens* Scudd. England.

Protophasma Brongn. Wings of large size; scapular nervure simple; neuration rather open except in the anal area, where it is made up of very crowded parallel veins mostly forked. Carboniferous. *P. Dumasi* Brongn. Commentry, France.

Breyeria Borre. Wings of moderate size, triangular, much broader next the base than beyond, the tip roundly pointed; scapular vein simple; neuration sparse. Carboniferous. *B. borinensis* Borre. Mons, Belgium.

Meganeura Brongn. Wings variable in size, long and slender, but broadest at base; scapular vein simple; all veins below this, except the

simple internomedian, with very abundant, closely-set, long, and mostly simple branches. Carboniferous. Two species. Commentry, France.

Ædœophasma Scudd. Wings of large size, broad, broadest in the middle; scapular vein simple; all below this with abundant, closely-set branches, forking abundantly toward their distal ends. Carboniferous. *A. anglica* Scudd. England.

Goldenbergia Scudd. Wings of moderate size, long and slender, generally broadest near the middle, but not prominently, the tip generally rounded. Scapular vein simple; branches of other veins oblique, curving down to and striking obliquely the lower margin of the wing, those of the externomedian vein occupying at least one-third of it; anal area extending nearly to the middle of the wing; no intercalary veins. Carboniferous. Five species. Bavaria, Saarbrück basin.

Haplophlebium Scudd. Wings of moderate size, exceedingly long and slender, the veins with rare dichotomosis; with or without intercalaries. Carboniferous. Two species. Nova Scotia and Pennsylvania.

Paolia Smith. Wings of variable size, long and slender; branches of veins dichotomizing strongly and running in a longitudinal direction, so that the externomedian branches occupy only a slight portion of the lower margin; no intercalaries. Carboniferous. Four species. Illinois, Indiana, and Pennsylvania.

In this section will probably fall *Archegogryllus priscus* Scudd., founded principally upon what appears to be a saltatorial leg of an insect. Carboniferous. Ohio.

2. Section **NEUROPTEROIDEA** Scudder.

1. Family **Palephemeridæ** Scudder.

Ancient May-flies, in which the lower externomedian stem seems to be formed on the same plan as the upper stem.

Here are placed three very different insects: *Platephemera antiqua* Scudd., from the Devonian of New Brunswick; *Ephemerites Rückerti* Gein., from the Lower Dyas of Saxony; and *Palingenia Feistmantelii* Fritsch, from the Carboniferous of Bohemia.

2. Family **Homothetidæ** Scudder.

Mediastinal vein terminating on the costa; scapular vein with no inferior branches; externomedian vein, usually the most important in the wing, conspicuously branched; internomedian vein similar to the last.

Acridites Andree. Remarkable for the great length of the mediastinal vein and its uniform distance from the margin. Carboniferous. *A. priscus* Andree (probably a hind wing). Bohemia.

Eucœnus Scudd. Body stout; the prothoracic segment twice as broad as long; abdomen ovate; fore wings with the mediastinal vein straight, terminating before the apical third of the wing with numerous

straight branches; scapular with similar branches ending half way between the mediastinal and the tip; externomedian important, with distant branches. Carboniferous. *E. ovalis* Scudd. Mazon Creek, Ill.

Gerapompus Scudd Body slender; the prothorax as long as broad; fore wings well rounded, the mediastinal arcuate like the costa, with infrequent simple branches; scapular ending near the tip. Carboniferous. *G. blattinoides* Scudd., *G. extensus* Scudd. Mazon Creek, Ill.

Anthracothremma Scudd. Body stout; the prothorax several times broader than long; wings subequal and elongated; the scapular vein arcuate and nearly reaching the tip; externomedian vein with numerous parallel branches, mostly simple. Carboniferous. *A. robusta* Scudd. Mazon Creek, Ill.

Genopteryx Scudd. Internomedian vein with branches very similar to those of the externomedian vein, the outermost in close proximity to the innermost branches of the latter. Carboniferous. *G. constricta* Scudd. Mazon Creek, Ill. *G. lithanthraca* Gold. sp. Saarbrück.

Cheliphlebia Scudd. Body rather slender, but wings large and coarse, without cross-veins; internomedian vein extending far toward the tip of the wing with many oblique branches. Carboniferous. *C. carbonaria* Scudd., *G. elongata* Scudd. Mazon Creek, Ill.

Genentomum Scudd. Wings large, elongated, with coarse venation and abundant cross-veins. Mediastinal vein very long, with numerous branches to the costa; other branches very distant and stout, the externomedian separated more widely than usual from the scapular, especially in the hind wing. Carboniferous. *G. validum* Scudd. Mazon Creek, Ill.

Didymophleps Scudd. All the veins and branches above the internomedian longitudinal and nearly parallel, nearly all the lower half of the wing being occupied by the oblique branches of the internomedian vein. Carboniferous. *D. contusa* Scudd. Vermilion County, Ill.

Homothetus Scudd. Mediastinal vein extremely long, scarcely surpassed by the scapular, and with scarcely any branches to the costa; externomedian vein with only a few branches in the outer fourth of the wing. Devonian. *H. fossilis* Scudd. New Brunswick.

Mixotermes Sterz. Mediastinal vein terminating at about the middle of the wing; externomedian with several distant oblique branches, the basal one thrown off far before the middle of the wing. Carboniferous. *M. lugauensis* Sterz. Lugau, Germany.

Omalia macroptera Coem.-Ben. probably belongs near here.

3. Family **Palæopterina** Scudder.

Mediastinal vein terminating on the scapular, not far from the middle of the wing; scapular vein with one inferior branch, which carries a few inferior longitudinal offshoots to the tip of the wing; externo-

median vein less conspicuous than the scapular branch, often simple; internomedian conspicuously branched with oblique offshoots.

Miamia Dana. Scapular vein lying close beside the mediastinal, its course straight, its main branch arising near the middle of the wing and nowhere very distant from the main stem. Carboniferous. *M. Bronsoni* Dana. Illinois.

Proptcticus Scudd. Scapular vein widely separated from the mediastinal, its course arcuate, its main branch arising near the base of the wing, parting rather widely from the main stem. Carboniferous. *P. infernus* Scudd. Illinois.

Dieconeura Scudd. Externomedian vein entirely simple; internomedian vein of unusual importance, extending far toward the extremity of the lower margin. Carboniferous. *D. arcuata* Scudd. Illinois. *D. rigida* Scudd. Pennsylvania.

Strephocladus Scudd. Externomedian vein simple, united by a prominent cross-vein with the main scapular branch near the base of the latter; internomedian vein terminating near the middle of the lower border, with numerous parallel branches arising from its superior surface and terminating on the lower border of the wing. Carboniferous. *S. subtilis* Kliv. sp. Schiffweiler, Germany.

Aethophlebia Scudd. Internomedian vein terminating before the middle of the lower border, emitting a single main branch beyond its middle, which is superior and, with the median fork of the externomedian and the larger part of the main scapular branch, forms a continuous adventitious vein crossing diagonally the course of the principal nervules of the wing; the ultimate offshoots of the externomedian vein arise indifferently from the main vein and the principal branch and are parallel and similar to the offshoots of the veins above. Carboniferous. *A. singularis* Scudd. Illinois.

4. Family **Xenoneuridæ** Scudder.

Mediastinal and scapular veins as in the Palæopterina; externomedian vein amalgamated at the base with the scapular and beyond the middle branching conspicuously; internomedian vein divided at the base into two simple branches. *Xenoneura antiquorum* Scudd. Devonian. New Brunswick.

5. Family **Hemeristina** Scudder.

Mediastinal vein terminating on the costa; scapular vein with one inferior branch arising in the basal half of the wing, running parallel to the main vein and supporting a considerable number of subequidistant oblique branches, occupying the apex or more than the apex of the wing; externomedian variable, generally branching considerably in its apical half; internomedian similar to the externomedian, but generally less important.

Lithomantis Woodw. Prothorax with large lateral lobes. Mediastinal vein farther from the margin in the middle than at base of wing; internomedian area fully as extensive as the externomedian. Carboniferous. *L. carbonaria* Woodw. Scotland.

Lithosialis Scudd. Mediastinal vein gradually approaching the margin all the way from the base. Internomedian area far less extensive than the externomedian. Carboniferous. *L. Brongniarti* Mantell sp. Coalbrookdale, England. *L. bohemica* Novák sp. Bohemia. *L. carbonaria* Germ. sp. Wettin, Germany.

Brodia Scudd. Scapular vein parallel to border; offshoots of its main branch distant, curving strongly downward, occupying a large proportion of the wing; base of the main scapular branch connected by a strong longitudinally oblique cross-vein with the externomedian. Carboniferous. *B. priscotincta* Scudd. Tipton, England.

Pachytylopsis Borre. Scapular vein arcuate, approaching the border gradually almost from the base; scapular offshoots longitudinally oblique. Carboniferous. *P. Persinairei* Borre. Mons, Belgium.

Lithentomum Scudd. Main scapular branch with a single or at most two branches, which are almost wholly longitudinal. Devonian. *L. Harttii* Scudd. New Brunswick.

Chrestotes Scudd. Main scapular branch straight, close, and parallel to the main stem, with comparatively few offshoots; principal anal vein deeply impressed. Carboniferous. *C. lapidea* Scudd. Mazon Creek, Ill.

Hemeristia Dana. Scapular branch strongly arcuate, at its base distant from the main stem, and at first taking the course of its basal offshoot. Carboniferous. *H. occidentalis* Dana. Mazon Creek, Ill.

6. Family **Gerarina** Scudder.

Mediastinal terminating on the costa; scapular vein the most important in the wing, with several offshoots, all arising from the main stem; externomedian vein with offshoots closely resembling those of the scapular vein, but generally less important; internomedian still less important, sometimes simple.

Polyernus Scudd. Body moderately stout; wings rather broad; mediastinal vein extending nearly to tip of wing; branches of scapular vein inequidistant at origin, very longitudinal, closely crowded and ramose, and yet hardly more important than the externomedian vein. Carboniferous. *P. complanatus* Scudd. Mazon Creek, Ill. *P. laminarum* Scudd. Pittston, Pa.

Gerarus Scudd. Body slender, tapering greatly anteriorly; wings slender; mediastinal vein variable; branches of scapular vein numerous, more or less longitudinal, simple or forked, occupying much more space than the branches of any other vein. Carboniferous. *G. vetus* Scudd., *G. mazonus* Scudd., *G. Danæ* Scudd. Mazon Creek, Ill.

Adiphlebia Scudd. Body rather stout and equal; wings rather broad; all the nervules simple, arising from their stems near the base of the wings, subparallel and longitudinal. *A. Lacoana* Scudd. Mazon Creek, Ill.

Megathentomum Scudd. Wings of great size, remarkably broad and rounded; most of the veins dividing into principal branches near the base, the branches longitudinal and again forking only near the margin. Carboniferous. *M. pustulatum* Scudd. Mazon Creek, Ill. *M. formosum* Gold. sp. Fischbach, Germany.

3. Section **HEMIPTEROIDEA** Scudder.

Eugereon Dohrn. The thoracic joints are twice as broad as long, while the head is slender, less than a fourth their width, with lancet-shaped mouth-parts and filiform multiarticulate antennæ; front and hind wings similar in size and shape and generally in structure, being long and elongated; mediastinal vein distant from, parallel to, and connected by transverse veins with the margin; scapular with a principal branch which parts widely from it; the nervules, which strike the lower margin, curve downward rapidly as they approach it; front legs very long, the tibiæ nearly twice the length of the femora. Permian. *E. Böckingi* Dohrn. Birkenfeld, Germany. Fritsch indicates a second species from Nyřan, Bohemia.

Fulgorina Goldenb. Mediastinal and scapular veins both terminating on the costal margin in the outer half of the wing, the latter with several basal branches, from the outer of which, which runs in close proximity to the main vein, most of the forking nervules take their rise; branches of the externomedian superior and parallel to the scapular branches; internomedian forked distally, the branches of the upper fork superior, of the lower fork inferior; anal area separated by an emargination from the rest of the wing. Permian. *F. Ebersi* Dohrn (sp.). Saarbrück basin.

The other species referred to Fulgorina as well as Goldenberg's *Macrophlebium Hollebeni* are probably hind wings of Palæoblattariæ.

Phthanocoris Scudd. An archaic heteropterous type, in which the front wing is already differentiated in structure from the hind wing, a large corium being present, distinct from the membrane, as well as a very narrow, unimportant clavus, the sutura clavi arising below the middle of the wing and reaching to the extremity of the corium; no embolium or cuneus exists and the mediastinal and scapular veins are widely separate at base. Carboniferous. *P. occidentalis* Scudd. Missouri.

4. Section **COLEOPTEROIDEA** Scudder.

These are perhaps indicated by the different borings brought to notice by Geinitz in the Coal Measures of Saxony and by Brongniart in the Car-

boniferous limestone of Autun. *Troxites Germari* Goldenb., from Saarbrück, is probably no insect at all—perhaps a fossil fruit.[1]

Brongniart has recently figured and briefly described an exceedingly interesting wing from the middle Silurian sandstone of Calvados, France, which he considers one of the Palæoblattariæ and has named *Palæoblattina Douvillei*. As a sketch kindly furnished me by Mr. Brongniart does not appear to support this reference, it is here placed at the end of the Palæodictyoptera, awaiting the fuller details concerning it promised by Mr. Brongniart.

B.—HETEROMETABOLA Packard.

Body generally bulky, flattened, and ill-constructed for varied flight. Prothorax large; the thoracic joints loosely compacted; abdomen generally sessile; mouth-parts generally mandibulate; front wings more or less coriaceous or with numerous and thickened veins, generally smaller than the hind wings, often reticulate. Metamorphosis generally incomplete, the pupa then active.

1. Order ORTHOPTERA Olivier.

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Body usually robust, often depressed or compressed; the integument coriaceous; ocelli generally present. Antennæ generally long, with rare exceptions simple and filiform. Mouth-parts adapted for biting; mandible stout, labium bifid. Pronotum large and distinct. Front wings coriaceous, in the flying species much smaller and especially narrower than the hind wings, which are plaited and sometimes transversely folded in repose, the anal area being very largely developed; membrane of both pair reticulate, with quadrangular cells. Female usually pro-

[1] See foot-note, p. 106.

vided with an ovipositor. Metamorphosis incomplete; terrestrial throughout life.

1. Family **Forficulariæ.**

The earliest record we have of earwigs is in the Lias of Schambelen, where an extinct genus, Basecopsis Heer, is found, which Heer looks upon as "a remarkable connecting link between the Orthoptera and the Coleoptera." Unfortunately the forceps are not preserved. The only other Mesozoic species is an obscure form from Solenhofen, called Forficularia by Weyenbergh.

In the Tertiaries they are more abundant, though rare. Menge and Gravenhorst speak of their occurrence in amber, Serres catalogues them as found at Aix, and four species are figured by Heer and Massalongo as occurring in the beds of Oeningen and Monte Bolca. But they are more abundant in American rocks, eleven species being found at Florissant, Colo.; all are referred to a single genus, Labiduromma Scudd., with unusually large eyes; some of them are of very large size, and some are preserved with the hind wings fully expanded, showing that as early as the Oligocene the peculiar structure of these organs was already fully developed.

2. Family **Blattariæ.**

This family is one of the most interesting of all that occur in Mesozoic rocks, as it is the only one at all well represented in the Trias. Reference has already been made to the genera of Palæoblattariæ (Etoblattina, Spiloblattina, Petrablattina, and Poroblattina) which are found either in part or exclusively in these oldest Mesozoic rocks. In addition to them we have the three following genera of Blattinariæ in the same deposits:

Neorthroblattina Scudd. Fore-wings ovate, diaphanous; tip rounded, but a little produced; mediastinal and scapular veins blended into one, occupying nearly half the wing, the main vein gently sinuous, but not reaching the apex, the veins terminating on the margin. Trias. Four species. Colorado.

Scutinoblattina Scudd. Fore-wings subtriangular, tapering, strongly convex at base, coriaceous, obscuring the venation; combined mediastinal and scapular vein straight and terminating below the apex. Trias. Three species. Colorado.

Legnophora Heer. Fore-wings ovate, coriaceous, obscuring the relations of the thickened veins and branches; mediastinal and scapular veins apparently blended and occupying nearly half the wing. Trias. *L. Girardi* Heer. Trebitz, Germany.

Cockroaches are also pretty abundant in the Jurassic rocks, over forty

species having already been figured, principally from the Upper Oölite of England. Among the more interesting of the Jurassic genera, very few of which have been properly studied, are the following:

Blattidium Westw. Remarkable for the extreme length, slenderness, and equal breadth of the wings. The scapular and externomedian veins are blended and, with the internomedian vein, send long, parallel, seldom forked branches to the outer margin of the wing. Lower Purbecks. Two or three species. England.

Rithma Gieb. Wings tapering from the base, the blended mediastinal and scapular area occupying half the wing and terminating at or below the tip. In other respects closely resembling the Triassic Neorthroblattina. Lias and Oölite. Four species. England and Switzerland.

Elisama Gieb. Wings rather stout; mediastinal and scapular veins blended and occupying the upper half of the wing; externomedian and internomedian veins curving very strongly downward at base and then running longitudinally; anal area reduced to a minimum. Upper Oölite. Two species. England.

Mesoblattina E. Gein. Wings slender, resembling the preceding, but the anal area of normal or even large size, and the externomedian and internomedian veins less abruptly curved at the base. Lias and Oölite. A dozen or more species. England, Germany, and Switzerland.

Pterinoblattina Scudd. Front wings resembling a feather with its shaft and barbs, the shaft, always straight and lateral, being formed of the parallel and approximate mediastinal, scapular, and externomedian veins; the barbs, of the long, straight, and mostly simple mediastinal and externomedian veins. Lias and Oölite. Six species. England and Germany.

Mesoblattina is by far the most abundant in species, many undescribed and unfigured forms existing in British collections, and especially in that of Rev. P. B. Brodie. A species of Blabera is described by Heyden from Solenhofen. There are also a considerable number of other generic types known in Mesozoic rocks, the whole number of species, both of Palæoblattariæ and of Blattariæ, amounting to between sixty and seventy.

Of Tertiary cockroaches, the remains are in general less perfectly preserved, excepting where they occur in amber. Something like a dozen species are known, and they have mostly been described or merely mentioned under the generic names of Blatta, Blattina, or Blattidium, by Germar, Heer, Menge, Berendt, Giebel, Heyden, and others, and have been recorded from Prussian and Sicilian amber, from Oeningen, Eisleben, Rott, Spitzbergen, and Greenland. Menge and Germar refer two amber species to Polyzosteria, Heer records as many species of Heterogamia from Parschlug, while the American species from Florissant and Green River belong to Paralatindia, Zetobora, and Homœogamia.

3. Family **Mantides.**

A single very obscure wingless specimen from Oeningen, *Mantis protogæa*, has been figured by Heer, and Guérin mentions the genus as occurring in amber.

4. Family **Phasmida.**

The only Postpaleozoic fossil of this family occurring in the rocks is a single specimen from the Oligocene of Florissant, in Colorado, belonging to the genus Agathemera and not very far removed from the genus Pseudoperla, peculiar to amber, of which two species are described by Pictet. Pseudoperla is remarkable for the shortness of the mesothorax and abdomen and the straightness of the fore-femora. Besides these, according to Menge, the amber has furnished specimens of Phasma and Bacteria. Considering the abundance of walking sticks in Paleozoic rocks, the absence of their remains from Mesozoic strata is rather remarkable.

5. Family **Acridii.**

A few obscure fragments, mostly saltatorial legs, have been found in the Lias of Switzerland and Upper Oölite of England, indicating the probable presence of the group of *Truxalidæ*, to which also and to *Œdipodidæ* a few wings from the Lias of Schambelen and of Dobbertin must be referred. These have been described by Heer and Geinitz under the names of Gomphocerites and Acridiites.

The group of *Acridiidæ* proper seems never to have occurred in a fossil state, since it is not only absent from the Mesozoic rocks but from the Tertiary deposits as well, the species of which, with the exception of a single one of the *Tettigidæ*, belong, like the Mesozoic forms, to the *Truxalidæ* and *Œdipodidæ*. To the former (*Truxalidæ*) belong *Œdipoda nigrofasciolata* Heer, from Radoboj; *Gomphocerus femoralis* Heer, from Oeningen; and *Acridium Barthelemyi* Hope, from Aix, together with a species of Gomphocerus and two species of Tyrbula Scudd., from Florissant, Colo. The last named is an interesting extinct genus allied to Syrbula Stål., with clubbed antennæ, hind tibiæ abundantly spined, and comparatively small eyes. To the *Œdipodidæ* probably belong five of the species of Œdipoda described by Heer from Oeningen and Radoboj, a species mentioned by Serres as occurring at Aix, and three American species from Florissant, belonging to as many genera, two of which, falling at opposite extremities of the Œdipodan series, are extinct. The only other fossil acridian published is a species of Tettigidea, described by Heer from Oeningen under the name of *Tetrix gracilis;* but an insect from Aix allied to Chimarocephala is in the Paris museum and Woodward mentions a species of this family from the Isle of Wight. Not a single specimen of this family has been reported from amber.

6. Family Locustariæ.

A few representatives only of this family have been found in Mesozoic rocks. Three or four species are known from Solenhofen and figured by Germar, Weyenbergh, and Hagen; one of them, *Locusta speciosa* Münst., is gigantic and all are obscure. Another species looked upon by E. Geinitz as a Gryllacris is described from Dobbertin; and when the Mesozoic species from England, figured by Brodie and Westwood, are more carefully studied, some will probably be found to fall here.

The Tertiary forms are not numerous: two species each of Decticus, Gryllacris, and Locusta have been described by Heer, Germar, and Fritsch from Oeningen, Radoboj, the Rhenish coal, Greenland, and Freudenhain in Bohemia, while single species of Locustites and Phaneroptera are figured by Heer from Parschlug and Oeningen. Serres also reports a species from Aix, and Capellini one from Gabbro. No specimen of this family seems to have been found in amber excepting a few larval forms figured by Germar.

It is a little difficult to place the fossil forms so far recorded from Europe, but the species of Decticus described by Heer and Fritsch, from Oeningen and Freudenhain, as well as Germar's *Locusta extincta*, appear to be *Decticidæ*. *Phaneroptera vetusta* Heer, from Oeningen, seems to fall in the *Phyllophoridæ; Locusta grœnlandica* Heer and perhaps Serres's species, in the *Pseudophyllidæ;* the two species of Gryllacris from Radoboj and the species indicated by Capellini, in the *Gryllacrididæ*. In America a single species of each of these groups, excepting the *Decticidæ*, belonging respectively to the genera Lithymnetes, Cymatomera, and Gryllacris, has been found at Florissant, together with one species each of Orchelimum and Locusta, representing the *Conocephalidæ*, a group which does not appear to occur fossil in Europe. Thus, although the total representation of the family in the Tertiary rocks is very feeble, all its principal subdivisions are present.

7. Family Gryllides.

The Lias of England and Germany presents a peculiar type of cricket, that from Dobbertin having been described by E. Geinitz under the name of *Gryllus dobbertinensis;* it is the only described Mesozoic species and its exact position is not clear.

The Tertiary deposits show a considerable variety of forms, though the species are not numerous. Only a single one has been fully described from amber and a second figured from Oeningen. Serres, however, mentions seven species as occurring at Aix, of which two are said to belong to Gryllotalpa (Heer also mentions a Gryllotalpa from Oeningen) and one to Xya, while he compares the four others to species of Œcanthus, Gryllus, and Nemobius. Heer's *Gryllus troglodytes*, from Oeningen, is probably a Nemobius, and the amber species, *Gryllus macrocerus*, one of the *Trigonidæ*. Three species occur in the Green River beds of Wyoming, all belonging to a single genus closely allied to Nemobius.

2. Order **NEUROPTERA** Linné.

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Body elongated, generally cylindrical, the integument coriaceous. Antennæ of variable length, but with rare exceptions simple and filiform. Mouth-parts adapted for biting; mandibles slender. Pronotum very variable. Both pairs of wings large, membranous, subequal; the membrane reticulate, with usually polygonal cells. Female rarely provided with an ovipositor. Metamorphosis complete (Neuroptera vera) or incomplete (Pseudoneuroptera); usually aquatic in early life.

The Pseudoneuroptera have been separated from the Neuroptera proper by most recent writers, either as an independent order or, fol-

lowing Erichson, as a part of the Orthoptera. There does not seem to be sufficient reason for considering them a distinct order and the nature of their metamorphosis offers the most valid ground for uniting them with the Orthoptera. Their retention, as here, with the Neuroptera is, however, defensible on paleontological grounds.

1. Suborder PSEUDONEUROPTERA Erichson.

1. Family Thysanura.

Notwithstanding the simple structure of this apterous group, it is not known earlier than Tertiary times[1] and would scarcely be known then but for the amber inclusions. The *Collembola* have not received a careful study since they were first described thirty years ago by Koch, who was content to employ for the most part the old and comprehensive genera, Podura and Smynthurus, into which he threw seven of the ten species described. The others were referred to Paidium and a new genus, Acreagris, which Menge looks upon as only the female form of the coccid genus Monophlebus. The *Cinura* received closer attention from Menge, and they are more numerous in species, about fifteen having been described by Koch and Berendt and by Menge, and they include some remarkable forms. One of them, described under the generic name Glessaria by Koch and Berendt, is with reason looked upon by Zaddach and Menge as a larva of some other neuropterous group. Menge briefly describes three extinct genera, Lampropholis, Lepidion, and Lepidothrix, to which five species are referred. Most of the species belong to Petrobius, but there is a single species each of Forbicina and Lepisma. A single specimen of one of the Cinura has been found in the American Tertiary deposits of Florissant and is remarkable for its broad and flat femora. Florissant has also furnished in considerable abundance specimens of a very anomalous creature believed to belong here, but to form a special group of Thysanura called *Ballostoma*, coming between the Cinura and Symphyla. Its head is reduced to nothing but mouth-parts and gullet, which formed an extensible soft proboscis, which when at rest was withdrawn beneath the hood-like prothoracic joint; the legs were strongly developed, with expanded and flattened femora and tibiæ and two-jointed tarsi terminating in a single claw; the abdomen was furnished with apical hooks apparently used for retrogressive motion. On account of the headless character of the creature it has been called Planocephalus.

2. Family Termitina.

It has generally been supposed that the white ants were present and tolerably well represented in Paleozoic rocks, but most of the species

[1]Since this was written, Charles Brongniart informs me that he has found a species of this group in the Carboniferous deposits of Commentry, France.

which have been referred to this family have been shown by recent researches to belong to the Protophasmida, and the others to various neuropteroid Palæodictyoptera. At least half a dozen species are known from the Mesozoic rocks, however, most of them from the Lias of England, Germany, and Switzerland, the most common type being the extinct genus Clathrotermes Heer, peculiar for its numerous, transverse, gently oblique cross-veins in the costal field and for the dark quadrate spots which usually accompany these and other cross-veins. If we are to follow E. Geinitz, the species must have been exceedingly variable. Two white ants also occur in the Oölite of Bavaria, which Hagen refers to Termes proper.

In Tertiary times they were more abundant, numbering already about one-fourth as many as the known living species; nearly every existing genus occurs, and, in addition, in American rocks an extinct genus, Parotermes, characterized by the presence of distinct inferior branches to the scapular vein, the slight development of the internomedian vein, with the large development of the externomedian, which runs more closely than usual to the scapular vein and has unusually longitudinal branches. The genera of Termitina are divided by Hagen into two sections, according to whether the scapular vein is branched or not; about two-thirds of the recent species belong to the section with simple scapular and one-third to the other section, while the proportion is exactly reversed in Tertiary types. Of the several genera, Parotermes is represented by three species at Florissant; Calotermes, by three species in amber and at Rott; Termopsis, by three in amber; Hodotermes, by six species at Oeningen, Radoboj, Schossnitz, and Florissant, but curiously none in amber; Termes, by three species in amber, at Oeningen, and at Radoboj; and Eutermes, by four species, equally divided between Radoboj and Florissant. Besides these, species have been indicated from Sieblos, Monte Bolca, and the Isle of Wight. All the specimens so far found, with two exceptions, have been winged; a single larva has been found in amber and one at Florissant. There is probably no group of Tertiary insects concerning which our knowledge is more exact than is the case with the white ants. Hagen has examined over one hundred and fifty specimens from amber and twenty-five specimens have been obtained from Florissant.

3. Family **Embidina.**

Of this anomalous and limited group, which Wood-Mason has recently attempted to show should be removed to the Orthoptera, a single species, *Oligotoma antiqua* Pict. sp., from amber, has been found fossil, represented, however, only by larval forms.

4. Family **Psocina.**

This group has been found fossil only in amber, but here in considerable abundance, since several of the species are represented by twenty,

thirty, or even sixty individuals, and fifteen species are recognized, about one-ninth the number of living species known, but nearly one-half as many as the species now living in Germany according to the latest monograph by Kolbe. These fossil species are divided among ten genera as follows: Troctes, 1; Sphæropsocus, 1; Empheria, 2; Archipsocus, 2; Amphientomum, 1; Epipsocus, 1; Cæcilius, 3; Philotarsus, 2; Psocus, 1; Elipsocus, 1. The genera Sphæropsocus, Empheria, and Archipsocus are peculiar to amber; the first mentioned, a most remarkable form, has the front wings developed into the semblance of elytra. It is worthy of note that, while in the existing fauna of Europe the groups to which Psocus and Elipsocus belong embrace about half the species, they include only one-seventh the amber fauna. Hagen and Kolbe are at variance on the interpretation of these facts.

5. Family **Perlina.**

With the exception of a fossil from the Eocene of the Isle of Wight, referred to this family, and of a species of Leuctra described by Hagen from the Miocene of Rott, all our knowledge of the Perlina in ancient times is through the amber deposits. Thirteen species are known, belonging to the genera Perla, Tæniopteryx, Leuctra, and Nemura, all existing genera, and the species present no peculiarities worth special mention, being similar to existing types in north temperate regions, though in no case identical with them. It is worth remarking, however, that the number of species known from Prussian amber is nearly half that of those now living in Austria.

6. Family **Ephemerides.**

Undoubted remains of four or five species of this family occur in the Oölite of Solenhofen, some of very large size, most of which have been described under the generic name Ephemera, but one, in which the neuration, so far as it goes, is perfectly preserved, has been referred to a new genus, Hexagenites. Eichwald also describes and figures under the name of Ephemeropsis a larva found in the Siberian Jurassic rocks.

Our knowledge of Tertiary species comes largely from amber inclusions, but Heer and Scudder each describe a species of Ephemera from Oeningen and Florissant, and the latter distinguishes in addition five species from Florissant in an immature state. Wilkinson has also found a species in Australia. The amber species are eight in number, three of which are species of Baetis and the others are distributed among the genera Leptophlebia, Palingenia, Potamanthus, and Cronicus, the last an extinct genus allied to Heptagenia, distinguished from it by the four-jointed forceps of the male and the shortness of the middle anal bristle.

7. Family Odonata.

The strongly limited group of dragon flies makes its appearance in the Lias in considerable variety and apparently as highly specialized as to-day, for no less than four tribes are present, the true Agrionina and the Cordulina alone being absent. *Æschnidæ* are the most abundant, the *Æschnina* being represented by a species of Æschna at Schambelen and the *Gomphina* by one species each of Petalura and Gomphoides from England. *Calopterygina* come next, with one species each of Tarsophlebia and Heterophlebia, both extinct genera, also from England, and finally a species of Libellula from England. The same relation holds in passing upward into the Oölite, where the Agrionidæ are added. Here we have thirty-two species, of which half are *Agrionidæ:* four *Agrionina*, and twelve *Calopterygina*, of five genera, mostly extinct, namely, Isophlebia, 2; Heterophlebia, 2; Stenophlebia, 3; Tarsophlebia, 1; and Euphæa, 4; three are *Æschnina*, of the genera Anax and Æschna; eight *Gomphina*, of some undetermined genera, besides Petalura and Petalia; and finally five *Libellulina*, of about as many genera, yet undescribed. A species of Gomphina has also been found in the Wealden of England. The lithographic slates of Bavaria afford numerous, sometimes wonderfully preserved, dragon flies, called by the workmen Stangenreiter or Schladen-Vögel, which have been carefully studied by Hagen. They lie on the stone with expanded wings and are generally larger than modern types; sometimes the most delicate veins are perfectly preserved. Most of them are referred to extinct genera.

Considering the comparative abundance of this group in the secondary rocks, one would expect to find a better representation in the Tertiaries than is the case, for, even counting all the species founded upon the immature stages as distinct from any of those established upon wings, the Tertiary species are less than twice as numerous as those from the secondary rocks. The subfamilies are about equally represented, though the *Agrionidæ* are a little in excess, and the species are very unequally distributed among the tribes. Thus there are twenty-two species of *Agrionina:* of the genera Agrion, 7; Lestes, 5; Argya, 1; Platycnemis, 2; Sterope, 1; Dysagrion, 3; Podagrion, 1; and Lithagrion, 2, the last four genera being extinct; while there is but a single species of *Calopterygina* known by a pupal form, from amber, a curious reversal of the proportion in Mesozoic rocks. The *Æschnidæ* are more equally balanced between the tribes, the *Gomphina* being represented by six species, of the genera Gomphus, Gomphoides, Ictinus, and Petalura, and the *Æschina* by nine, of the genera Æschna, 8, and Anax, 1. The *Libellulidæ*, however, have again only a single species of *Cordulina*, but sixteen species of *Libellulina*, all except one, a Celithemis, referred to Libellula in a broad sense. Nearly every locality where Tertiary

insects are found, even including amber, has supplied its quota of this family, and some localities, such as Oeningen, have furnished the larvæ and pupæ in great numbers.

2. Suborder NEUROPTERA VERA Erichson.

1. Family Sialina.

This group was well represented in Mesozoic times, but the species have never been carefully studied or compared. Three species are found as far down as the Trias (of Switzerland), and referred to Chauliodites, while in Oölitic rocks are found, especially in the Lias and Purbecks of England, but also in the Dobbertin Lias, a considerable number of types, which have been referred to species of Rhaphidium, Sialium, Chauliodites, and Hagla, of which the last is the prevailing type. *Mormolucoides articulatus* Hitchc. is the larva of a species of this group found abundantly in the new red sandstone of the Connecticut River in New England, and is the oldest larval form of insect which has been detected. An interesting relic is also found in the Laramie group of Colorado in the immense oötheca of Corydalites, an insect allied to Corydalis, preserved in considerable numbers, and from which the eggs can be extracted. Marquis Saporta informs me that entirely similar remains are found in the lower Garumnian beds of Provence, France.

In Tertiary deposits this family is rare. In Europe it is known only from amber, and is there represented by one species each of Inocellia and Chauliodes; in America only the section of *Rhaphidiidæ* is found, but of this no less than four species of Inocellia and one of Rhaphidia, from the single locality Florissant; all these Tertiary genera exist at the present day.

2. Family Hemerobina.

The only Mesozoic forms which can certainly be referred to this family are those reported from Solenhofen. Hagen catalogues a Chrysopa, an Apochrysa, and a Nymphes. Weyenbergh figures a Chrysopa and two species of Hemerobidæ, one of which may very likely be an Apochrysa, and the actual species be thus reduced to four. All references of English secondary insects to this family appear to be erroneous.

In Tertiary times the species do not appear to have been numerous, but they represent nearly every one of the principal groups. Of the *Myrmeleonidæ*, an obscure species, from Radoboj, is referred by Charpentier to Myrmeleon, and Burmeister and Berendt mention seeing the same genus in amber, but they probably mistook something else for it. Of *Ascalaphidæ* Oustalet describes an Ascalaphus from Le Puy, and Hagen a Suphalasca from Stösschen. Neither *Nemopteridæ* nor *Mantispidæ* have been found, but *Hemerobidæ* and *Chrysopidæ* are not uncommon. Of the former, two species of Hemerobius, besides a larva, are described

from amber, and another species is mentioned from the Isle of Wight; one species each of Nymphes and Osmylus is found in amber, and a second species of Osmylus from Florissant. All these are existing genera, but an extinct genus, Bothromicromus, remarkable for its numerous sectors, occurs in British Columbia. Two other extinct genera occur in Colorado in the next group, the *Chrysopidæ*, Palæochrysa with one and Tribochrysa with three species. A species doubtfully referred to the *Chrysopidæ* is figured by Andrae from Thalheim, and a Coniopteryx from amber represents the *Coniopterygidæ*.

3. Family **Panorpidæ**.

To this family have generally been referred a considerable number of small wings occurring almost exclusively in the English and German Lias, to which the generic term Orthophlebia was applied by Westwood. Apparently it covered a considerable variety of forms, a dozen or more species having been named and many more being known, embracing a considerable range of neuration. In general the wings were of small size and had only faint cross-venation, if any, and the scapular and externomedian veins (which, being much bifurcated, bear almost all the branches) are blended at the base. Giebel has referred one of them to Panorpa, but it is of the same general character as the others, which form a distinctively oölitic type of Neuroptera, ranging as high as the Purbecks.

Nothing of this type appears in the Tertiaries, where Panorpidæ are very rare. Three species of Bittacus are described from amber and Radoboj and two species of Panorpa from amber and Colorado. The amber species of the latter genus is of a uniform ash-gray, but the species from Florissant is heavily banded, more so, indeed, than in modern types. Besides this, Florissant furnishes an extinct genus Holcorpa, with one species, remarkable for the complete absence of any cross-nervules, in which it reminds us of the Mesozoic forms; but, unlike them, it is conspicuously marked with large pale spots on a dark ground.

4. Family **Phryganidæ**.

The name of Phryganidium was given to a wing from the Lower Purbecks of England by Westwood, and, following him, E. Geinitz has described a number of species from the Lias, where this type of wing seems to be abundant and rather easily confounded with the species of Orthophlebia. These seem to be the sole representatives of the Phryganidæ in the Mesozoic rocks, excepting a tube-like larval case described by Fritsch from the Cretaceous of Bohemia.

Similar larval cases, made of minute particles of stone or of shells cemented together, have been found in various Tertiary deposits, at Oeningen, at Leistadt near Dürckheim, at Lewes in England, in Wyoming, even in amber, but particularly in Auvergne, where the so-called

indusial limestone, often 2 to 3 meters thick and of wide extent, is formed of their relics. These were described by Bosc eighty years ago. Excepting in America, however, remains of the imago have rarely been found in the rocks themselves, single examples being known at Aix, Parschlug, and Manebach, in the Isle of Wight, and in Greenland; and their absence is the more unaccountable since they are more numerous in amber than any other group of insects excepting Diptera and comprise more than half the specimens of Neuroptera and Pseudoneuroptera combined. Twenty-five species have been described by Hagen and Pictet, and several others mentioned, while nearly as many are known from Florissant. They belong largely in both cases to *Hydropsychidæ*, Polycentropus being the prevailing type in amber and Derobrochus in Colorado. This last is an extinct genus allied to Polycentropus, but distinguished by the length of its cells and the apparent want of any fifth apical cell. The other groups, represented both in amber and at Florissant, are the *Phryganidæ* proper, to which the remains in the rock deposits of Europe also belong; the *Limnophilidæ*, to which group most of the larval cases probably appertain; and the *Leptoceridæ;* while the *Hydroptilidæ* and *Rhyacophilidæ* are only known, and sparingly, from amber.

3. Order **HEMIPTERA** Linné.

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Body usually ovate and flattened, especially above; the integument coriaceous. Head more or less imbedded in the prothorax. Eyes small, ocelli generally present. Antennæ of variable length, filiform, most of the joints long. Mouth-parts prolonged into a beak adapted for piercing and sucking; the lancet-shaped mandibles and maxillæ, the latter without palpi, lying in a partly closed tube formed by the labium. Pronotum large and distinctly marked, though soldered broadly to the rest of the thorax. Mesothoracic scutellum large and distinctly marked. Front wings larger than the hind pair, either coriaceous at base and more or less membranous at tip or wholly membranous, but then of firmer texture and with stouter veins than the hind wings, and often

coriaceous at extreme base; veins of both wings generally few and distant, excepting next the front edge; when reticulate, the cells quadrangular; wings never folded. Legs slender, occasionally expanded, with never more than three tarsal joints. Metamorphosis (excepting in the male Coccidæ) incomplete. The terrestrial or aquatic habits (as the case may be) persistent throughout life.

1. Suborder HOMOPTERA Latreille.

1. Family **Aphidæ**.

A few unquestionable remains of this family are found in the English Wealden, one species, *Aphis valdensis* Brodie, having the characteristic neuration of the wing preserved, showing that it belonged to the *Schizoneurinæ*.

In Tertiary rocks, notwithstanding their delicacy and small size, they are not infrequent. About one hundred specimens, for instance, have been found at Florissant, including about eight species, most of which are referred by Buckton to extinct genera; and Menge's collection of amber insects in 1856 included fifty-six specimens of plant-lice. Besides this they have been found at Oeningen, Radoboj, Aix, Ain, and in British Columbia. Most of the species have been referred to Aphis (12), and Lachnus (8), and so belong, like the bulk of living species, to *Aphidinæ* proper, but Heer describes from Oeningen a Pemphigus, one of the *Pemphiginæ*, Berendt mentions a Schizoneura from amber, and one of the Florissant species also belongs to the *Schizoneurinæ*.

2. Family **Coccidæ**.

The only known fossils of this group are some that occur in amber. Three species referred to Monophlebus were described and figured by Germar, and Menge has since added short descriptions of half a dozen species referred to Aleurodes, Coccus (2), Dorthesia, and the extinct genera Ochyrocoris and Polyclona. The female of one of the species of Monophlebus was taken for one of the Poduridæ by Koch and considered the type of a new genus, Acreagris.

3. Family **Fulgoridæ**.

The oldest known member of this group is a very obscure fossil from the middle Oölite of Solenhofen, which Weyenbergh considers a Lystra; but the middle Oölite of England has furnished a few species referred doubtfully by Brodie to the genera Ricania, Cixius, Asiraca, and Delphax, the true relationship of which is still obscure; other Solenhofen species have been referred to Ricania, but are found to belong to the cockroaches (Pterinoblattina).

The family is fairly well represented in Tertiary rocks, some thirty species being known, distributed among half as many genera. The amber species comprise more than half the whole number, and are mostly referred to Cixius, but also to Pœocera, Pseudophana, Flata, and Ricania. The European rocks have furnished single species of Asiraca (Aix), Pseudophana (Oeningen), and Tettigometra (Radoboj), while from America we have single species of Planophlebia (an extinct genus), from British Columbia; of Aphana and Delphax, from Utah; and of Mnemosyne, Lystra, Fulgora, Cixius, Aphana, and the extinct genus Lithopsis, from Wyoming, besides some large undescribed forms from Florissant.

4. Family **Membracides.**

A single species found in the Oölite of Belgium and mentioned by de Borre as probably belonging near Tettigonia is the only Mesozoic form referable here.

Tertiary species are tolerably abundant and have been mostly referred to existing genera: Acocephalus, 3, sp.; Jassus, 2; Tettigonia, 6; Bythoscopus, 4; Typhlocyba, 5; and Cœlidia, 1; though Heer refers one Radoboj species to an extinct genus, Dictyophorites; five species, from Oeningen, Radoboj, and Aix, to Cicadellites; and one Oeningen species each to Membracites and Ledophora. More than half the known species come from Radoboj or amber, but four species are known from Oeningen, three from Aix, two from Utah, and one each from Wyoming, British Columbia, Florissant, and Stösschen.

5. Family **Cicadellina.**

Nearly a dozen species, referred loosely to Cercopis, Cercopidium, Cicadellium, and some to "Cicada," have been described from the Lias of Dobbertin and Schambelen and the upper Oölite of England, but they have not yet been carefully studied.

In Tertiary deposits they are the most abundant of Homoptera. No less than sixteen species of Cercopis are described, more than half of them from Radoboj, the others from Oeningen, amber, and British Columbia. A genus allied to Ptyelus is represented at Florissant by a dozen or more species, very abundant in individuals, and seven species of Aphrophora are known from amber, Aix, Oeningen, Radoboj, and Greith, on the Upper Rhone. Besides these, an interesting extinct gigantic genus, Petrolystra, with two species, remarkable for the coloration of the wings, has been found at Florissant. Heer describes a Cercopidium from the Miocene of Greenland and Woodward refers a species found in the Eocene of the Isle of Wight to the existing *Triecphora sanguinolenta.*

6. Family **Stridulantia.**

The presence of this group in Mesozoic rocks, so far as published data are concerned, rests mainly on disputed or disputable data. Two species

coming from Solenhofen, referred by Weyenbergh to Cicada, are very obscure objects. Several other species from England which belong to the preceding family have been referred to Cicada. But Brodie possesses what appears to be the pupa of a Cicada from the Lias of England and the Stonesfield slate has furnished a wing of large size, named *Paleontina oolitica* by Butler and by him considered a butterfly, which is looked upon by Scudder as belonging to this family of Homoptera.

In the Tertiaries three species found at Radoboj and one at Oeningen have been referred by Heer to the genus Cicada and are species of medium size; but besides these Serres refers to a species of the same genus at Aix and Berendt and Burmeister state that it occurs in amber, while Bleicher mentions a specimen of this family from the Tongrian of Rouffach in Alsace. None have been discovered in America and none in amber.

2. Suborder HETEROPTERA Latreille.

1. Family **Notonectidæ**.

This family of water bugs makes its first appearance in the Tertiaries, and then in very scanty numbers. Two species of Corixa are known, one each from Oeningen and Stösschen, and one has been mentioned from Florissant. One species of Notonecta also is known from Kutschlin, another from Rott, a third is mentioned from Aix, and a fourth occurs at Florissant.

2. Family **Nepidæ**.

Species referred to Naucoris and Nepa, occurring in the Oölite of Solenhofen, are the only known representatives of this family in Mesozoic times.

To the same genera are referred two species occurring in the Tertiary deposits of Oeningen, where, also, a species of Diplonychus is found. Berendt states that a species of Nepa occurs in amber and Serres refers to one found at Aix, where, according to Hope, a species of Ranatra also occurs.

3. Family **Belostomidæ**.

To the genus Belostomum have been referred three species from the Oölite of Solenhofen. One of these was originally described by Germar under the name of *Scarabæides deperditus*, under the supposition that it was a beetle. Dr. Zittel informs me that some specimens in the Munich museum preserve the stout legs and principal wing nervures, showing a complete general agreement with Belostomum. Another species referred here by Germar under the name of *Belostomum elongatum* is considered by Assmann to be rather a Hymenopteron, allied to Sirex. (See p. 96, note.)

In the Tertiaries, two species of Belostomum have been figured, one from Oeningen, the other from the Rhenish brown coal.

4. Family **Hydrometridæ.**

Obscure species referred to the genera Velia and Hydrometra have been found in the Oölite of Solenhofen and of England and a few genera are represented in Tertiary deposits. Species of Limnobates and Hygrotrechus have been described from Oeningen and British Columbia and of Limnacis, Halobates and Hydrometra from amber, and mention has been made of the occurrence of the latter genus and of Gerris at Aix. Halobates also occurs at Florissant.

5. Family **Saldidæ.**

Germar describes a single species of Salda from amber.

6. Family **Reduviidæ.**

Two gigantic species in the Solenhofen shales represent this family in the Mesozoic; they have been referred to the genus Pygolampis and an extinct type allied to it, called Propygolampis.

In the Tertiaries the true *Reduviina* are the most abundant, six species of Harpactor being found at Oeningen or Radoboj, with a species of Evagoras at Oeningen and one of Reduvius in Wyoming. Reduvius occurs also at Aix and in amber, according to Serres and Germar. Of the other tribes, as in the Reduviina, all the genera are of existing types; a single species of Pirates is found at Radoboj, one of Platymeris in amber, two of Stenopoda at Oeningen, and Serres reports a Ploiaria at Aix. A number of species of undetermined genera occur at Florissant.

7. Family **Nabidæ.**

Nabidæ of the modern genera Nabis and Prostemma are found at Oeningen, and several species of the former occur also at Radoboj and in amber.

8. Family **Aradidæ.**

The fossil species of this group are all from Tertiary deposits and have been referred to Aradus; three species have been described from amber and one from Radoboj, besides which Hope and Serres refer to a species at Aix and Scudder to two species at Florissant.

9. Family **Tingidæ.**

Half a dozen Tertiary localities have already furnished specimens of these delicate insects. Species of Monanthia are described from Oeningen and Krottensee and of Tingis from Radoboj and Prussian amber. Besides this, specimens of Tingis have been found at Aix and at Florissant.

10. Family **Capsidæ.**

Amber has furnished a large number of species of this family, all referred to living genera. Germar describes thirteen species of Phytocoris and Gravenhorst specifies without describing five species of Miris. Both Berendt and Gravenhorst mention also a Capsus from the same deposits and Curtis speaks of a Miris from Aix.

11. Family **Physapodes.**

One would scarcely look for remains of these minute insects in the rocks, and yet they are not extremely rare, eight species of the genus Thrips having been described, three each from Aix and from amber and two from Oeningen. Another species found at Aix is made the type of a new genus, Calothrips, and the rocks of Utah have furnished one species each of three genera, Melanothrips, Lithadothrips, and Palæothrips, the last two extinct and the last remarkably preserved, the microscopic hairs of the fringe of the wing being distinct enough to be counted.

12. Family **Lygæidæ.**

The two oldest insects which have been referred to this group are a Pachymerus from Strensham and a Pachymeridium from Dobbertin, both from Liassic deposits; they are both rather obscure, and almost more so are the three wings figured by Westwood from the English Purbecks, which Giebel refers to Lygæites.

In Tertiary deposits the family is comparatively abundant and widespread. No less than seventeen described species are referred to Pachymerus: From Aix, 6; Oeningen, 4; amber, 3; Radoboj, 2; Sieblos; and Utah; nine to Lygæus: from Radoboj, 3; Oeningen, 2; Sieblos, 2; Aix; and Krottensee; while Serres alludes to four species of the same genus at Aix and Heer describes five species of the extinct Lygæites from Oeningen and Radoboj. Besides this, Heer describes six species of Heterogaster from Radoboj, Aix, and Oeningen, and one extinct genus, Cephalocoris, from Oeningen, Heyden refers to a species of Micropus found at Stösschen, and Scudder describes a Rhyparochromus from Wyoming. The numerous species from Florissant are not yet worked up.

13. Family **Coreidæ.**

Our knowledge of this family in Mesozoic times is limited to the brief account and figures of Liassic species given by Heer in his Urwelt der Schweiz, who figures two and names one additional species referred to extinct genera, Protocoris and Cyclocoris. Eight species in all were known to Heer, and they are very perfectly preserved.

A considerable variety occurs also in the Tertiaries, including, according to Heer, three genera which are extinct, Berytopsis, Hermostites,

and Palæocoris, each with a single species, the first two from Oeningen, the last from Radoboj; also, Coreites, which includes three more obscure forms from Radoboj and Oeningen, whose generic relation is uncertain. The same author also describes four species of Syromastes from Oeningen and two of Spartocerus from Radoboj. Oeningen has also furnished single species of Hypselonotus and Alydus; a species of the latter genus occurs in the Rhenish coal, of Leptoscelis, at Sieblos; Serres mentions a species of Coreus at Aix and Menge a species of Berytus in amber. The family is abundantly represented in the still unworked field of Florissant, where especially one or two species of Alydina are exceedingly abundant in individuals.

14. Family **Cimicidæ.**

A number of species from the English Purbecks, and even from the Lias, have been referred to this family, but all these remains are exceedingly obscure and have in no case been referred to special genera.

In the Tertiary deposits, however, this family is the most numerous and abundant of all Heteroptera, but no one of its members has been referred to extinct genera. Species of Cimex, using the term doubtless in a general way, have been mentioned by Eser as occurring in the Miocene of Unterkirchberg, by Serres, Berendt, and Schlotheim as found in amber, and by Stainton as occurring in the Pleistocene marls of Ulveston. Three species of Acanthosoma are described by Heer from Radoboj, as well as one of Phlœocoris from the same place; and, among the series of the Pentatomids, one species of Ælia, four of Eurytæna, two of Eusarcus, two of Halys, and eight of Pentatoma, all from Oeningen, besides two of the latter genus from Radoboj and one each from amber, Salzhausen, and Atanekerdluk in North Greenland. Serres also referred to three species as found at Aix, a species of Euschistus is described from British Columbia, and a considerable number of the Pentatomid series occur at Florissant. Finally, four species of Pachycoris and a species of Tetyra are found at Oeningen.

15. Family **Cydnida.**

This restricted group was tolerably abundant, varied, and widespread in Tertiary times. An extinct genus, Cydnopsis Heer, is represented by eleven species in Oeningen, Radoboj, and Aix, and the recent genus Cydnus, by four at Aix, Oeningen, and Wyoming, besides a species near Cydnus found in the Australian Tertiaries. Another extinct genus, Neurocoris Heer, has two species at Oeningen; Cyrtomenus and Æthus, one each in Wyoming; and Brachypeltus, one at Krottensee. Several species of Corimalæna and its allies are found at Florissant.

4. Order COLEOPTERA Linné.

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Body compact, generally subelliptical; the integument usually corneous. Head usually inserted more or less deeply into the prothorax. Antennæ exceedingly variable in length and in the form of the joints; ocelli generally absent. Mouth-parts adapted for biting; the mandibles stout, labium entire. Pronotum large, distinct, free. Mesothoracic scutellum small, but distinctly marked. Front wings corneous, nearly all traces of the veins lost, adapted to the shape of the body, separated from each other by a straight suture down the middle of the back, useless in flight. Hind wings membranous, folded transversely and longitudinally in repose; the veins few, distant, incomplete, a joint being formed near the extremity by their erasure; cross-veins very

rare; reticulation absent. Metamorphosis complete, the appendages of the pupa free. Larva of three principal types (thysanuriform, eruciform, and vermiform or apodal), not corresponding to the divisions based on the main structural distinctions of the adult. Habits variable, but the aquatic forms aquatic throughout life.

1. Series RHYNCHOPHORA Latreille.

1. Family **Anthribidæ.**

This family made its first appearance in the Tertiaries. Oeningen, Rott, and Green River (Wyoming) have each furnished a pair of species, the species from Oeningen being referred to Anthribites, those from Rott to Choragus and Tophoderes, and those from Wyoming to Brachytarsus and Cratoparis. In addition, Berendt mentions a species of Anthribus from amber.

2. Family **Scolytidæ.**

Not altogether rare in the Tertiaries, being found in the earliest deposits that have yielded insects: amber, Aix, and the Green River shales. A species of Platypus is described from Prussian and another from Sicilian amber; one species each of Trypodendron and Dryocœtes, from Wyoming. Serres mentions species of Scolytus and Hylurgus from Aix. Heer describes a Hylesinus from the same place and Menge speaks of three species of this genus in his amber collection, besides larvæ of the same. Berendt and Serres also mention its occurrence in amber and Germar describes a species from the same deposit under the generic name Hylesinites.

3. Family **Calandridæ.**

A few species of this family have been recovered from the Tertiaries. Heer describes two species of Cossonus and one of Sphenophorus from Oeningen. Oustalet describes one of the former from Aix and Heyden one of the latter from Rott. Besides this, the only reference is to a species in amber, referred by Pictet to Calandra.

4. Family **Curculionidæ.**

In attempting to bring together the scattered references to this and allied families of Rhynchophora it has often been impossible, from the nature of the reference or the obscurity of the fossil remains, to determine to which family it belonged; so far as possible they have been separated, but where no clew could be obtained they have been brought under the head of the present family.

We have in this group some of the oldest Coleoptera known. One species (*Curculionites prodromus* Heer) comes from the Trias and bears the unmistakable stamp of this group. Two others described by Heer

occur in the Rhaetic of Sweden, but are represented only by elytra. The Lias of Switzerland has furnished the same author seven species, of which he has figured a couple under the generic name of Curculionites and Sitonites. They occur also in different parts of the oölitic series, a species of Curculionidium being figured from the Stonesfield slate of England, and several species of Curculionites and one of Hypera from the Purbecks of England. Finally Heer figures two species from the Greenland Cretaceous under the genera Curculionites and Archiorhynchus.

Corresponding to this we find the family one of the very richest in species in the Tertiary rocks. About one hundred species have already been indicated, referred almost exclusively to existing genera; probably a nearly equal number have been found at Florissant alone, and of the amber species little is known. Menge mentions sixty-three specimens in his amber collection; Oustalet describes a species of Balaninus from Aix, and Deichmüller one from Kutschlin; Pictet mentions a Baris from Aix, and Scudder describes a Eurhinus from Florissant. Fliche found the recent *Mononychus punctum-album* in peat at Jarville. Oustalet describes a Cœliodes from Aix and Heyden a Ceutorhynchus from Rott. Distinct species of Cryptorhynchus have been found in Wyoming, at Aix, and at Rott. Heyden describes an Acalles from Rott, and Deichmüller a Chalcodermus from Kutschlin, while Hope and Serres indicate a Rhinobates as occurring at Aix. A single species of Nanophyes has been described from Rott, one of Gymnetron from Green River, and Serres indicates a Cionus from Aix. The *Tychiini* are represented by a Sibynes at Aix and a Tychius at Rott; the *Anthonomini* by a Rhynchænus at Aix and an Anthonomus at Florissant; two species of Magdalis are described by Heyden from Rott; Oustalet describes a Bagous from Corent, and from Aix one species each of the genera Hydronomus, Tanysphyrus, and Erirhinus. Notaris and Dorytomus have also been mentioned from Aix, and the latter as well as Erirhinoides from amber. Heer describes two species of Lixus from Oeningen, a genus also occurring at Aix. Heyden describes a Rhinocyllus from Rott. No less than thirteen species of Cleonus are described from Aix, Oeningen, and Corent. Besides an extinct genus, Cleonolithus, described by Bassi from Sinigaglia, a new genus Meristos is described by Murray from Nágpur in India. Species of Larinus are mentioned by Heer and Heyden from the Miocene deposits of Oeningen and Rott and the same genus was recognized by Burmeister among the insects of Aix. Eight species again of Hylobius have been obtained from various localities in Germany, Switzerland, France, Italy, and Wyoming, as well as indicated from amber; a species of Plinthus is found at Aix, another at Corent, and one of Pissodes at Sieblos, besides an indication of the latter in amber; two species of Phytonomus are found at Aix, another in amber, four of Hipporhinus, and one of Hypera, also from Aix. Two species of Apion have been described by Heer and by Heyden, from Oeningen and Rott, respectively, and other species are mentioned by Berendt as occurring in amber, and by Serres at Aix.

Oustalet also describes a Coniatus from Aix; Heyden, a Eurychirus from Rott; and five species of Sitones are described from Oeningen, Rott, Aix, and Wyoming. Besides these we have eleven species of "Curculionites" of uncertain position, mostly described by Heer, from Oeningen, Radoboj, Schossnitz, Corent, Aix, Corfe, and Spitzbergen. References to Rhynchophora are also made from the following localities not otherwise mentioned: Antrim, Dorset, Bournemouth, Lexden, the Isle of Wight, the British Isles, and Nágpur (India), where they form the larger proportion of those found.

5. Family **Otiorhynchidæ.**

The only references to the occurrence of this family in Mesozoic deposits are an Anisorhynchus described by Weyenbergh from Solenhofen and a fragment of an elytron from the Cretaceous of Bohemia, which Fritsch figures under the name of Otiorhynchites.

In Tertiary deposits they are numerous, though not so numerous as the preceding family, bearing perhaps the same relation to them, in point of numbers, as at the present epoch. Phyllobius, Polydrosus, and Thylacites are all said by Burmeister to occur in amber, and the last genus has been found by Deichmüller at Kutschlin. Heer describes a Naupactus from Oeningen and Serres says one occurs at Aix. Heer also describes a diluvial Laparocerus from Madeira, Scudder a Eudiagogus from Wyoming and an Entimus from Utah, while Smith mentions a species referred doubtfully to Strophosomus as found at Peckham, England, in lower Eocene beds. A species of Ophryastes and two of Otiorhynchus are described from Wyoming, and Heer mentions four existing species of the latter genus as found in the glacial clays of Schwerzenbach, Switzerland. Heer also describes an extinct genus, Pristorhynchus, from Oeningen. Finally, of the *Brachydermi*, Heyden describes a Liparus from Sieblos, and Curtis mentions, while Giebel describes, one from Aix. Three species of Epicærus are recognized from Wyoming, two of Anisorhynchus from Kutschlin and Corent, and two of Brachyderes from Aix. No extinct genera of this tribe are yet recognized. Many unpublished forms of this family occur at Florissant.

6. Family **Byrsopidæ.**

Four existing genera of this group have been recognized in Tertiary rocks. Of Brachycerus four species are described, from Oeningen two, from Gergovie and Aix one each, and from Aix Serres recognized three species as of this family, one of which Oustalet suggests may be *Hipporhinus Heeri* Germ. Serres also refers to a Meleus at Aix, and a species of Brachymycterus has been described from Rott.

7. Family **Attelabidæ.**

Heer describes a species of Attelabus from Oeningen.

8. Family **Rhynchitidæ.**

Oeningen and Rott have each furnished two species of Rhynchites, and to the same genus have been referred single undescribed species from amber and Aix; in addition to these, a species of Antliarhinites has been described from Oeningen and one of Eugnamptus from Wyoming.

2. Series HETEROMERA Duméril.

1. Family **Stylopidæ.**

One of the most curious results of Menge's studies of the amber fauna was the discovery of an extinct genus of this abnormal type of beetles, which in its earliest stages lives parasitic in the abdomen of winged bees and wasps. A single male specimen was found, which, on account of the trifid antennæ, he named Triæna.

2. Family **Rhipiphoridæ.**

Heyden describes a Myodites from Rott and Stein a Rhipidius from amber. Berendt and Menge also mention the existence of Rhipiphorus in amber.

3. Family **Meloidæ.**

The occurrence of this family in Mesozoic rocks is exceedingly doubtful, the only claim to it being in a figure published by Weyenbergh, without comment, of a very obscure object from Solenhofen, which he names *Meloe bavaricus*.

As to the Tertiaries, Heyden describes a Mylabris from Rott; Heer, a Lytta and a Zonites from Oeningen and a Meloe from Radoboj; the last genus and Cantharis are also mentioned by Goldfuss as occurring on the Rhine, and by Menge, Berendt, and Burmeister as found in amber. Hammerschmidt exhibited a species of this family from amber at Vienna, which Redtenbacher looked upon as the type of an extinct genus, and Menge states that among the *Cantharidæ* of his amber collection are found beautiful and remarkable objects. He also states that he possesses one specimen of amber "with seven reddish-yellow larvæ resembling Meloe larvæ at the stage when they live on flowers and then attach themselves to bees; but they possess only two claws at the tip of the two-jointed tarsi." A good many specimens of this family have been found at Florissant.

4. Family **Pyrochroidæ.**

Berendt includes in his list of amber insects a species of Pyrochroa.

5. Family **Anthicidæ.**

This family is not very rare in amber, Menge's collection containing twenty-seven specimens; but none have been described, Berendt

only mentioning an Anthicus. A species of this genus has also been described from Aix by Oustalet.

6. Family **Mordellidæ.**

This family also is abundant in amber, but none have been described excepting *Mordellina inclusa* Germ. Berendt also mentions Mordella as occurring in amber.

7. Family **Œdemeridæ.**

Berendt mentions Œdemera in amber.

8. Family **Pythidæ.**

Berendt includes Anaspis among the amber insects of Prussia and Guérin mentions a species in Sicilian amber. Heer also describes a Pythonidium from the Miocene of Spitzbergen.

9. Family **Melandryidæ.**

Besides a species of Mycterus described by Heer from Oeningen, we have a Scraptia figured by Guérin from Sicilian amber, and a Hallomenus or Orchesia mentioned by Berendt from Prussian amber.

10. Family **Lagriidæ.**

F. Smith refers an amber insect figured by him to a genus allied to Statira.

11. Family **Cistelidæ.**

This family occurs in the Mesozoic rocks, Heer describing a species from the Lias of Schambelen under the name of *Cistelites insignis.*

In the Tertiaries little is known of them. Berendt mentions Cistela as found in amber and Heer describes a species of this genus from Oeningen, as well as four species, which he refers to Cistelites, from Greenland, the island of Sachelin, and Oeningen.

12. Family **Tenebrionidæ.**

An elytron found in the Lower Lias or Rhaetic of Hildesheim is figured by Roemer under the name Helopides. A species of Tenebrio is described by Weyenbergh from the middle Oölite of Solenhofen, but the upper Oölite of England has furnished a considerable number of species, nine of which have been referred by Giebel or by Westwood to Tentyrium, Pimelia, Blaps and Blapsium, Tenebrio, Crypticus, Helopium, Helopidium, and Diaperidium. They are mostly composed of fragments of elytra. (See, also, page 106, note.)

Considering its extent at the present day and the tolerable variety in Mesozoic times, the representation of this family in the Tertiaries was

not very large. The Rhenish brown coal has furnished species of Boletophagus, Tenebrio, Uloma, Gonocephalum, and Platydema; Tenebrio is also recorded from British Columbia, and Boletophagus, as well as Hopatrum, from amber. A recent species of the last-named genus, *H. sabulosum*, is stated by Meyer to be found in the marls of Hochheim. Aix has also been credited with a species of Hopatrum, as well as with Asida and Sepidium. Species of Helops have been found at Eisleben, Lausanne, and Oeningen, and one, *Helops wetteravicus*, first described by Heyden, from Salzhausen, is said by Heer to occur also in Greenland. An extinct genus, Tagenopsis, is described by Heer, from Oeningen, and *Helopini* are said by Westwood and Brodie to occur in the English Tertiaries. About twenty species of Tenebrionidæ have been found at Florissant, but they are not at all abundant in individuals.

3. Series PHYTOPHAGA Duméril.

1. Family **Bruchidæ**.

All the fossil (Tertiary) species of this family have been referred to existing genera. The brown coal of the Rhine has furnished the greatest number, viz, two species of Bruchus and one each of Caryoborus and Urodon. Oeningen has also its species of Bruchus and Caryoborus, and a species of Bruchus has been described from Utah and another indicated from Aix. A dozen or more species of this family have been found at Florissant, only one of which, a Spermophagus, has been described.

2. Family **Chrysomelidæ**.

Fairly represented in Mesozoic rocks, beginning with the Trias, a species of Chrysomelites having been described by Heer from the Lettenkohle of Rütihard, in Basel. The Lias of England has furnished several figured but unnamed species, besides two referred to Chrysomela, and Heer figures from Schambelen a couple of forms under the name of Enmolpites and Chrysomelites, of which he says it is "difficult to say what kind of leaves they might have fed upon." The Oölite of Bavaria and of England has furnished also some six species referred to Chrysomela, besides species of Cryptocephalus and Cassida in the former.

In the Tertiaries species of this family are very abundant and are almost exclusively referred to existing genera. Of the *Cassidini* we have four species of Cassida figured from Oeningen, Aix, and Rott, besides many references to the genus at Aix, in amber, and in the Lexden peat. Of the *Hispini*, Menge says that Odontota occurs in amber and Heer describes an Anoplitis from Oeningen. Of the *Galerucini* we have an extinct genus, Oryctoscirtetes, in the Florissant beds, besides three species of Galeruca described from Radoboj and Oeningen, and numerous references are at hand to the occurrence of the latter genus and of Haltica in amber. Adimonia was also found by Fliche in peat at Jarville and a Galerucella

by Scudder in British Columbia. The *Chrysomelini* proper were even more numerous: eight species of Chrysomela have been described from Oeningen, Aix, and amber, besides four species of Chrysomelites from Alaska, Greenland, and Spitzbergen. Numerous references to the occurrence of Chrysomela in amber occur—a genus which, according to Menge, is the richest in numbers of all Chrysomelidæ; he even records three larvæ of this genus similarly entombed, and its occurrence at Aix and in Lexden peat is also on record; Wollaston also found in the Lexden peat a species of Oreina and three species of the same genus are described by Heer from Oeningen; three species of Lina are figured from Oeningen, Rott, and Salzhausen, a species of Plagiodera from Rott, and four species of Gonioctena from Oeningen, Aix, and Schossnitz. Colasposoma, one of the *Eumolpini*, is credited to amber by F. Smith. Cryptocephalus is described from Wyoming and is said by Menge to occur in amber. Of the *Clythrini*, Heyden describes a Labiostomis from Rott and a Clythra from Salzhausen, while Heer describes a second Clythra from Oeningen. Of the *Criocerini*, two species of Lema are figured from Salzhausen and Oeningen and two of Crioceris from Aix and amber. Of the *Donaciini*, Berendt says that Hæmonia occurs in amber and six extinct species of Donacia are described from the Quaternary at Sonnaz and Leffe, and from the older formation of Schossnitz, Oeningen, and Spitzbergen. As many existing species are recorded from the Quaternary deposits or interglacial clays of Leffe in the Val Gandino; at Chambéry, La Boise, and Ardres, in France; at Lausanne, Utznach, Dürnten, and Schwerzenbach, in Switzerland; at Hösbach, in Franconia; and at Durchheim, in Pfalz; besides which, undetermined species are mentioned from similar deposits in Flanders; at Villechétif and Vannes, in France; and at Mundesley, in England. Chrysomelidæ of undetermined genera are recorded from Creech, Schossnitz, Hérault, and Florissant, the last place furnishing over twenty species.

3. Family Cerambycidæ.

The lower, middle, and upper Oölites are all credited with some species of this family. Two species of Prionus are found in the lower members in England, and one of these also in the Dobbertin Lias; Leptura, Mesosa, and Saperdites all occur at Solenhofen, and Prionus and Lamia, in the English Purbecks. These are nearly all recognized by the elytra alone. Besides these Geinitz has described and figured in the Quadersandstein of various localities in Saxony borings of beetles in fossil wood, which are credited to insects of this family under the name of Cerambycites.

A considerable variety, though no great number of species, has been found in the Tertiary deposits; with few exceptions they have been referred to existing genera, and these exceptions all occur in the *Lamiinæ*. Thus Deichmüller refers a species from Kutschlin to Mesosites, Scudder one from Florissant to Parolamia, and Motschulsky indicates

an amber species under the name of Dorcadionoides. Allied to these Heer describes a Mesosa and a Lamia from Oeningen, Heyden a Lamia and Dorcadion from Rott, and Berendt states that Lamia occurs in amber. Heer describes also two species of Acanthoderes from Oeningen and Heyden an Oberea from Rott, while four species of Saperda are described from the Miocene deposits of Oeningen and the Rhine and the same genus is recorded from amber. Casts of large insect larvæ are also sometimes found in amber, one of which is referable to Saperda. Such casts are generally very rare and have indeed not been known a great while. They all belong to larvæ of this family and the next. Of the *Cerambycinæ* proper, Leptura is recorded as found in amber, both as larva and imago. Necydalis also occurs in amber, three species of Clytus are described from Oeningen and Aix and a Trachyderes from Sieblos. Obrium and Molorchus are recorded from amber and two species are described from the Rhenish brown coal under the name of Hesthesis. Cerambyx has been found in amber, both as imago and larva, and is recorded also from Oeningen, Aix, and the Rhine. Heyden describes a Hylotrupes from Rott and Heer two species of Callidium from Oeningen. Species of this last genus have also been referred to as found in amber, at Aix, and in the Quaternary deposits of Utznach. Fifteen or twenty undescribed species of this family occur at Florissant.

4. Family **Spondylidæ.**

Two species of Spondylis are described by Giebel and Germar from amber and the Rhenish coal, and Goldfuss states that a Parandra is found in the latter. The larva also of Spondylis occurs in casts in amber.

4. Series LAMELLICORNIA Latreille.

1. Family **Scarabæidæ.**

A few representatives of this family have been found in Mesozoic deposits, and even as far back as the Lias, which has furnished in England a fragment referred to Melolontha and in Switzerland a smaller form called Aphodiites. Besides these we have in the Oölite of Solenhofen species which have been referred to Oryctes and Cetonia, and possibly some of the other larger beetles from those deposits will prove to belong here. *Scarabæides deperditus* Germ. belongs to the hemipterous family Belostomidæ. The Carboniferous fossil from Altenwald, described under the name of Troxites, is probably a fruit.

Species of this family are abundant in the Tertiaries and are almost without exception referred to existing genera. Among the *Cetonini* we have five species of Trichius and one of Valgus, described by Heer, from Oeningen. Serres speaks of members of this group as occurring at Hérault and Curtis catalogues a Cetonia from Aix. Of the *Dynastini*,

two species of Pentodon are described from Rott and Oeningen, and the last has furnished a Scarabæus, a genus also recognized by Bertrand at Glarus. Among the *Rutelini*, Heyden describes an Anoplognathus from Rott, and four species of Anomala are figured from Oeningen and Rott, while a new genus, Anomalites, is established by Frič for a fossil found lying in a very natural position in a cavity of the Süsswasserquarz of Nogent-le-Rotrou. Among the *Melolonthini* Fliche recognizes the recent *Rhizotrogus solstitialis* in the peat of the Flemish coast and Heer describes an extinct species from Oeningen. Heer recognizes the the modern *Melolontha hippocastani* in the glacial clays of Schwerzenbach and describes a fossil form from Greith, and Novák another from Krottensee; while for six other forms from Oeningen and Parschlug, Heer establishes the new genus Melolonthites. Serres also recognizes Pachypus among the Aix relics. Of the *Sericini* we have only a Lepitrix and a Serica described by Heer from Oeningen, besides a species of the latter genus mentioned by Giebel as found in amber. A species of Glaphyrus from Oeningen is the only representative of the *Hoplini* and one of Trox from British Columbia of the *Trogini*. The *Geotrupini* are more abundant, and include an extinct genus, Coprologus, described by Heer from Oeningen, a Bolbocerus from Kutschlin, with four extinct species of Geotrupes from Aix, Oeningen, and the Rhine, besides three existing species of the same genus in the Pleistocene of Vannes and in the peat below the till in Edinburgh. A species of Hybosorus from Oeningen represents the *Hybosorini*, and six species of Aphodius described from Oeningen, amber, Rott, and the bone caves of Pennsylvania, besides the mention of one from the Polirschiefer of Habichtswald, represent the *Aphodiini*. The *Coprini*, again, are both abundant and varied. Oeningen has furnished five species of Onthophagus, three of Gymnopleurus, two of Copris, and one each of Glaphyrus and Oniticellus. Curtis also recognizes *Copris lunaris* L. in the Pleistocene of Mundesley and Oustalet describes an Onthophagus from Aix; besides these, Horn recognizes in the relics from the bone caves of Pennsylvania species of Phanæus and of Chœridium. Heyden describes an Onitis from Rott and Serres recognizes Sisyphus at Aix. Some thirty species of undetermined genera of this family have been found at Florissant.

2. Family **Lucanidæ**.

Germar describes a Platycerus from the Rhine, Deichmüller a Dorcus from Kutschlin, and Motschulsky figures a Dorcasoides from amber. Platycerus is also recognized in amber by Berendt, Dorcus in the Eocene of the Isle of Wight by Woodward, and Lucanus in the Rhenish coal by Goldfuss and by Giebel. Menge also mentions the occurrence of a single Lucanid in his amber collection.

5. Series SERRICORNIA Latreille.

1. Family Cioidæ.

This little family is represented by a Cis and by a Microzoum described from Rott by Heyden. Berendt also recognizes Cis in amber.

2. Family Lymexylidæ.

Heer names, but neither describes nor figures, *Hylecœtus cylindricus*, from Oeningen; besides this, Atractocerus and Lymexylon have been recognized in amber, the latter in both the imago and the larval state.

3. Family Cupesinæ.

Motschulsky notes in amber a species which he calls a Cupoides, from its resemblance to Cupes, and the latter is mentioned in his list of amber insects by Berendt.

4. Family Ptinidæ.

Brongniart describes from the Cretaceous of Lottinghem a fragment of wood with perforations of a beetle, which he ascribes to a Bostrychus. The same genus is recorded as occurring in amber by Burmeister, Hope, and Menge, the last recognizing the larva as well as the imago. Lyctus and Apate are also both said to occur in amber, and the latter at Aix as well. Of the *Anobiinæ*, Dorcatoma, Anobium, and Ptilinus are recorded from amber, the first also in a larval condition. Anobium is stated to occur also in the Isle of Wight, and three species, as well as one of Sitodrepa, are described from Wyoming. Ptilinus is also mentioned by Heyden as found at Salzhausen, and the same author describes an extinct genus, Xyletinites, from Rott. Among the *Ptininæ*, two species of Ptinus are described by Heyden from Rott and Stösschen and the genus is also recognized in amber and at Aix. Eight or nine species of the family occur at Florissant.

5. Family Cleridæ.

Heer describes a Clerus from Oeningen and Giebel one from amber. Menge's amber collection contained fourteen specimens of this family and Berendt catalogues species of Corynetes, Opilo, and Tillus. A single species is found at Florissant.

6. Family Malachidæ.

Heer describes a Malachius from Oeningen, and this genus, Dasytes, and Ebæus have been found in amber.

7. Family Lampyridæ.

Heer states that three species of this family have been found in the Lias of Schambelen and one of Brodie's species from the Lower Lias of

Forthampton is referred by Giebel to Telephorus. In the Lower Purbecks of Durdlestone Bay Westwood figures a somewhat similar form under the name of *Telephorium abgarus*.

The family is moderately abundant in the Tertiaries and the species are all referred to existing genera. Telephorus claims nine described species from Oeningen, Rott, and Radoboj; Chauliognathus, Lampyris, and Luciola, one each from Florissant, Oeningen, and Rott, respectively. Lampyris is also stated to occur in amber, as are also Lycus and Malthinus.

8. Family **Buprestidæ**.

This family appeared as early as the Trias, a species of Glaphyroptera and one of Buprestites being described by Heer from Vadutz; the Rhaetic also has a species from Sweden referred to Buprestites. It was already abundant in the Lias, where no less than thirty-three species and seven genera were recognized by Heer at Schambelen; indeed, no other family contained half so many species, and it comprised more than 28 per cent. of all the Coleoptera. Two of the genera specified, Euchroma and Melanophila (2 sp.), are existing types, but Glaphyroptera (6 sp.), Micranthaxia (2 sp.), Buprestites, and Chrysobothrites are extinct types. A large proportion of these species are undescribed. A species of Buprestites is also recognized by Heer in the Lias of Pechgraben, Austria, and one is figured by Blake from the English Lias; four or five other Liassic species figured in Brodie's work are also referred to this family, some under the name of Ancylocheira. The Oölite of England furnishes several species, referred mostly to Agrilium, Buprestis, and Buprestidium, and consisting largely of single elytra, while in the Oölite of Solenhofen the genera Buprestis and Chrysobothris have been recognized.

Although abundant in Tertiary deposits, this family is not so predominating as its past history in the Mesozoic period would lead us to anticipate. It contains, however, a larger proportion than usual of generic types deemed extinct, Murray finding one, Lomatus, in the Tertiary deposits of Nágpur, in Central India, and Heer three, Protogenia, Füsslinia, and Buprestites, the last with three species, at Oeningen. Heer also finds species of this latter genus at Sieblos, Bovey Tracey, and in Greenland, and Giebel four others on the Rhine. Among modern genera we have Agrilus, single species described from Rott and others recognized at Creech and in amber; Acmæodera, two species at Oeningen; Sphenoptera, one species each at Oeningen and at Salzhausen; Chrysobothris, one species each at Stösschen and at Florissant; Anthaxia, seven species at Oeningen, Salzhausen, and Naumburg; Dicerca, five species at Oeningen, Salzhausen, Rott, and Naumburg; Perotis, five species at Oeningen, Rott, and Monte Bolca; Ancylocheira, ten species in the same localities; Buprestis, eight species in the Rhenish coal and British Columbia, besides unnamed species at Aix and in amber, both in the imago and the larval condition; Capnodis with three, Chalcophora with two, and Eurythyrea with one

species, at Oeningen. Besides these, references have been made to the occurrence of unmentioned genera of the family in the Eocene of Bornemouth, Creech, and Dorset and in the peat of Lexden, in England, and a considerable portion of the beetles of Nágpur, in India, are referred here. They are rare in amber, Menge having but four specimens in his collection of over eight hundred Coleoptera. At Florissant, in Colorado, about thirty species have been found.

9. Family Throscidæ.

Heer figures *Trixagites floralis* from the Lias of Schambelen and Berendt catalogues Throscus from amber.

10. Family Elateridæ.

This family is abundant in Mesozoic rocks, commencing with the Lias, where, in Switzerland, ten species are recognized by Heer, some of which retain to some extent the coloration of the elytra. Megacentrus and Elaterites are the names given by Heer to the only two species he has figured, and the latter genus is also recognized by him in a species from the Jura of Irkutsk, Siberia. Roemer describes under the name of Elateropsis a species from the Rhaetic of Hildesheim, and the English Lias has furnished half a dozen species figured by Brodie and named by Giebel, all as of the genus Elater. Three species of Elater and one of Lacon are credited to the Solenhofen Oölite, and seven species of Elater and Elaterium to the English Purbecks.

The family was abundantly and variously represented in the Tertiaries, but the number of species referred to extinct genera is relatively small. Heyden describes Silicernius from Rott, Giebel Elaterium from Corfe, and to Elaterites are referred by Heer and Deichmüller four species from Oeningen, Greith, and Kutschlin; four species also are referred to Elater from Oeningen, Spitzbergen, and amber, and numerous references to the same genus are made from Aix, Utznach, Mundesley, Peckham, and Basel. Oeningen has besides furnished among the true *Elaterini* (to which it is probable all the foregoing refer), species of Diacanthus, Ischnodes, Corymbites, Cardiophorus, Lacon, Ampedos, Limonius, and Adelocera, of which genera Cardiophorus and Limonius are recognized in amber, and a species of Corymbites described from Wyoming. Oxygonus has two species in Utah, Cryptohypnus one in Wyoming, besides being recognized in amber, and Campsosternus one at Kutschlin. Among the *Eucnemini* we have only an Epiphanis from Utah and the genera Microrhagus and Eucnemis recognized in amber. Elateridæ of undetermined position have also been recognized at Florissant and in British Columbia and in amber. Menge had no less than one hundred and thirty specimens in his amber collection, and nearly as many are known from Florissant, including a great many species.

11. Family **Dascyllidæ.**

A minute species of Cyphon, figured by Brodie and named by Giebel, has been found in the Purbecks of England and recognized also by Geinitz in the Lias of Dobbertin.

The same genus has been recognized in the Prussian amber and in the Tertiaries of New South Wales. Scyrtes is also catalogued by Berendt from amber; the genus Ptilodactyloides was founded on a species also found in amber, and Atopa has been recognized at Aix.

6. Series CLAVICORNIA Latreille.

1. Family **Parnidæ.**

An elytron from the English Purbecks, referred doubtfully to Limnius by Brodie and described by Giebel as an Elmis, is the only reference to this family in the Mesozoic.

2. Family **Byrrhidæ.**

Five species of this family, of which three are named and two of these figured under the generic title Byrrhidium, have been recognized by Heer among the Lias insects of Schambelen.

Scarcely more than this is known of the family in Tertiary times. Three species of Byrrhus are described from Rott and Oeningen, and the same genus and Limnichus are recognized by Berendt among the insects found in amber.

3. Family **Lathridiidæ.**

A single species, *Lathridiites Schaumii* Heer, is found in the Lias of Schambelen.

In the Tertiaries Heer describes a Corticaria from Aix and Berendt specifies Lathridius in his catalogue of amber insects.

4. Family **Trogositidæ.**

Heer recognized four species of this family in the Liassic beds at Schambelen, but figures only one, for which he establishes a new genus, Cycloderma.

Trogosita is recorded by Serres at Aix, and nine species of the same are described from Oeningen, the Rhenish basin, and Greenland; two species of Peltis are also described from Oeningen and Rott, and Oeningen has furnished a species of Gymnochila.

5. Family **Nitidulidæ.**

Heer mentions seven species of this family as found in the Lias of Schambelen, but mentions specifically only *Nitidulites argoviensis* and *Petrorophus truncatus.*

They are not very abundant in the Tertiaries, considering the present extent of the family. Rhizophagus, Ips, Strongylus, and Nitidula are all said to occur in amber, and six species of Nitidula and two of Amphotis have been described from Radoboj and Oeningen. A species of Prometopia from British Columbia and one of Phenolia from Wyoming complete the list, excepting that half a dozen undescribed species of different genera are found at Florissant.

6. Family **Histeridæ**.

The only Mesozoic representative is an obscure specimen from Solenhofen, referred by Weyenbergh to Hister.

The same genus is represented at Oeningen by eight species; two species of Hister are found in amber, according to Menge, and half a dozen species of undetermined position occur at Florissant.

7. Family **Dermestidæ**.

This family has not been recognized below the Tertiaries, and is not abundant there, a single species of Attagenus having been described by Heyden from Salzhausen and one of Dermestes by Heer from Oeningen. Both Anthrenus and Dermestes are, however, said to occur in amber and two or three species of the family are found at Florissant.

8. Family **Mycetophagidæ**.

A single species referred to an extinct genus, Prototoma, is stated by Heer to occur in the Swiss Lias and a species of Triphyllus is described by Oustalet from Aix.

9. Family **Cryptophagidæ**.

Two species referred to an extinct type, Bellingera, figured by Heer from the Lias of Schambelen, represent this group in Pretertiary times.

The only Tertiary species known are an Atomaria from Oeningen, an Antherophagus from Wyoming, and a Cryptophagus said to occur in amber.

10. Family **Cucujidæ**.

Three species of Sylvanus and one of Passandra are said by Menge to occur in amber.

11. Family **Colydiidæ**.

A species of Cerylon described by Brodie from the English Purbecks is the only known Mesozoic species.

The Tertiary species are known only from amber, Stein describing two species of Bothrideres and Berendt cataloguing Colydrinm.

12. Family **Erotylidæ.**

A species of Mycotretus is described by Scudder from Wyoming.

13. Family **Endomychidæ.**

In amber have been found a species of Lycoperdina, according to Menge, and Motschulsky figures a species under the new generic term Phymophoroides.

14. Family **Coccinellidæ.**

Either referred to Coccinella or simply to the family are two species from the upper Lias or lower Oölite of England, one in the middle Oölite of Solenhofen, and three or four in the upper Oölite of England.

In the Tertiaries we find a Lasia and a Sospita at Rott and twelve species of Coccinella about equally divided between Oeningen and Rott and in no case recognized in both localities. Coccinella has also been found in the Lexden peat and at Aix as well as in amber, where Menge records a larva. Scymnus is also recorded from amber and eight or ten species of the family occur at Florissant.

15. Family **Phalacridæ.**

Berendt catalogues a Phalacrus from amber.

16. Family **Scaphidiidæ.**

An obscure fossil from Solenhofen is described and figured by Weyenbergh as a Scaphidium.

In the Tertiaries Heyden figures a new genus, Seniaulus, from Rott. Heer describes a Scaphisoma and a Scaphidium from Oeningen and the latter genus is recognized in amber.

17. Family **Staphylinidæ.**

Brodie figures two rove-beetles from the English Purbecks, which Giebel describes under the genera Philonthus and Prognatha, respectively; these appear to be the only Pretertiary members of the family.

In Tertiary times, however, the family was abundant and had a varied representation, though all the generic types but two or three are recognized as still existing. One of the extinct genera, Protactus Heer, with two species, was thought by him to represent a new subfamily group, *Protactidæ*, whose nearest relations were with the *Homalini*. Of this latter type we have a species of Anthophagus from Rott and a Homalium from Radoboj, while both genera are said to occur in amber. Of the *Oxytelini* we have two species of Bledius from Oeningen and Wyoming and two of Oxyporus from Oeningen and Rott, besides both of these from amber, and from Oeningen and Utah two species of Oxytelus, a genus recognized by Moore in the Tertiaries of New South Wales. The

Tachyporini are represented by a single described species of Tachyporus from Rott, though not only this genus but Tachinus and Mycetoporus occur in amber, the first-mentioned abundantly. Of the *Pæderini*, Oustalet describes two species of an extinct genus which he calls Erinnys[1] from Aix, a locality which has also furnished one species each of Achenium, Lithocaris, and Lathrobium; the last-named genus has also species described from Oeningen and Wyoming, and, besides, Heyden has described a Sunius from Rott and Berendt recognized a Stilicus from amber. The *Stenini* are represented by three species of Stenus from Aix and Rott, and it has also been found in amber. Of the *Staphylinini*, there are Quedius with two species at Aix and Philonthus with three at Aix and Rott (both of these genera being recognized also in amber), Xantholinus at Aix, Leistotrophus in Utah, Staphylinites in Wyoming, and eight species of Staphylinus at Aix and Oeningen; this last genus has also been recognized in both Prussian and Sicilian amber, on the Isle of Wight, at Rott, and in Italy. Finally, of the *Aleocharini*, Myrmedonia and Aleochara have been recognized in amber, a species of Hygronoma has been described from Aix, and one of Gyrophæna from Utah. Nearly thirty species of the family have been found at Florissant, but are not yet published.

18. Family Pselaphidæ.

We know this family in a fossil state only from amber inclusions. Motschulsky recognized two genera, which from their relation to living forms he called Eupsinoides and Tmesiphoroides. Berendt notes there the presence of Bryaxis, Euplectes, and Pselaphus, and Menge that of Bythinus.

19. Family Paussidæ.

Menge mentions the occurrence of Paussus in amber. Motschulsky figures from Menge's collection a species which he recognizes as a distinct type, Paussoides, and Stein describes an Arthropterus from the same.

20. Family Scydmænidæ.

Oustalet describes a Scydmænus from Aix, Berendt recognizes the same genus in amber, and Motschulsky mentions as found in amber a distinct type, Scydmænoides.

21. Family Silphidæ.

An obscure Solenhofen fossil is figured by Weyenbergh as a Silpha. Besides this the only Mesozoic form is a fragment from the Cretaceous of Kounič, referred by Frič to Silphites.

[1] This name is preoccupied in Lepidoptera (Schrank, 1801). It may be called Lithoplanes (λίθος, πλάνης).

The family is poorly represented in the Tertiaries. Anisotoma and Catops are credited to amber and four species of Silpha are described from as many localities: Oeningen, Radoboj, the Rhine, and Spitzbergen. Besides these Heer has recognized the recent *S. dispar* Herbst in the glacial clays of Schwerzenbach. Two other species of the family have been found in a single example, each, at Florissant.

22. Family Hydrophilidæ.

This family was abundantly represented in Mesozoic times. Its first recognition is in the Rhaetic, Heer describing a specimen of Hydrophilites from Sweden. In the Lias of Switzerland no less than fifteen species have been recognized by Heer, where, next to the Buprestidæ, they are the most abundant of beetles at Schambelen. Only a few of the species have been described or figured by Heer, but these have all been referred to extinct genera: Hydrophilites (3 sp.), Wollastonites, and Hydrobiites. The English Lias has also furnished a species referred by Giebel to Berosus, and the Purbecks of the same country several species figured by Brodie and referred by Giebel to Helophorus (2 sp.), Hydrophilus (2 sp.), and Hydrobius, besides some unnamed forms. Weyenbergh also looks upon the *Scarabæides deperditus* of Germar, from the Oölite of Solenhofen, as a Hydrophilus, but it is rather a Belostoma. (See p. 61.)

The family is equally well represented in Tertiary times. A species of Cercyon from British Columbia represents alone the *Sphæridini*. Of the *Hydrobiini*, an extinct genus Escheria, with two species, is described by Heer from Oeningen, and has, perhaps, another on the Rhine; two species of Berosus are known from Wyoming, four of Laccobius from Aix, Corent, Rott, and Wyoming, two of Philhydrus from the last, and six of Hydrobius from Oeningen, Aix, Spitzbergen, and Wyoming. The *Hydrophilini* are the most abundant, showing two species of Tropisternus from Wyoming, six of Hydrous from Oeningen and Rott, and eleven of Hydrophilus from Aix, Parschlug, Chexbres, and Oeningen, besides the interglacial beds near Basel. *Hydrophilus piceus* L. has also been recognized by Sordelli in Italian peat, and the genus has been recognized at Florissant and in the Isle of Wight. Heer also describes two extinct genera, Hydrophilites and Hydrophilopsis, the former with a species from Greenland, the second with one from Oeningen, to which Oustalet adds a second from Aix. The *Helophorini* are represented by two species of Helophorus from Oeningen and one of Ochthebius at Rott.

7. Series ADEPHAGA Clairville.

1. Family Gyrinidæ.

The Lias furnishes a considerable number of species of this family, Heer finding seven in Switzerland and two being known from England. Heer refers all his species to Gyrinites and Gyrinus, but only figures

four of them, all but one Gyrinites. The two English species are both figured by Brodie and named Gyrinus by Giebel. The only other Mesozoic form known is a Gyrinus from Solenhofen.

They are not so abundant in the Tertiaries, the only extinct species known being three of Dineutes from Oeningen and one from amber referred by Motschulsky to a distinct genus Gyrinoides. Gyrinus is also recognized by Menge in amber and the modern *G. natator* L. and *G. marinus* Gyll. were found by Heer in the glacial clays of Switzerland at Schwerzenbach and Basel.

2. Family **Dytiscidæ.**

This family has not been recognized in the Swiss Lias, but the English has furnished a single species referred to Laccophilus. The Oölite of Bavaria and that of England each possesses a species of Dytiscus and one of Hydroporus.

It is tolerably abundant in the Tertiaries, but all the species have been referred to existing genera. Cybister is represented by three species at Oeningen and Locle, Eunectes by one at Corent, Hydaticus by two at Oeningen, Dytiscus by six at Oeningen and Höhgau in Miocene beds, and at Merla, Italy, in the Quaternary, besides which the genus has been recognized in the Isle of Wight Tertiaries, on the Rhine, and at Aix. Heer describes two species of Colymbetes, from Oeningen and Radoboj, and one is recognized at Aix by Hope; Heyden describes an Agabus from Rott and Menge says it occurs in amber, while Aymard quotes two species of Necticus as found at Le Puy. Heer again describes two species of Hydroporus from Oeningen and a Laccophilus from Spitzbergen, and the latter genus has been recognized in Utah. Heyden describes a Pelobius from Rott.

3. Family **Carabidæ.**

This family is one of the most abundant in species, whether in Mesozoic, Tertiary, or present times. It reaches back to the Rhaetic, Heer having found one species among those of Sweden examined by him, which he refers to the extinct genus Carabites. In the Lias they are more plentiful, Heer having found eleven species at Schambelen, although he has only named and figured four, of which he refers three to Carabites and one to the extinct genus Thurmannia. One of the species of Carabites has also been recognized at Dobbertin, and an additional species in the Austrian Lias. Three species in the English Lias figured by Brodie are referred by Giebel to Harpalus. The Oölites have furnished a greater variety of forms, a dozen species from the English Purbecks having been referred by Giebel to Carabus, Harpalus, Cymindis, and Camptodontus, and by Westwood to Harpalidium; one species of Carabus also is found in the lower Oölite of England, and species referred to Carabus and Carabicina have been found in the middle Oölite

of Solenhofen. Lastly, Frič figures under the name of Brachinites a fragment of an elytron from the Cretaceous of Bohemia. (See p. 106, note.)

In the Tertiaries this family is very abundant and varied, especially among the *Harpalinæ*. In the *Harpalini* proper, Harpalus has eleven species from Rott, Aix, Oeningen, and Radoboj, besides the recent *H. lævicollis* in the glacial clays of Schwerzenbach and others reported from amber and the Pliocene of Mundesley; Heer describes also one species each of Sinis and Dichirotricus from Oeningen. Of the *Chlæniini* we have only the genus Chlænius, two species of which are known, one from amber and the other from the bone caves of Pennsylvania. Of the *Brachynini*, a single species of Brachynus from Oeningen. Of the *Helluonini*, a species of Polystichus from Aix, another reported in amber, and one of Helluomorpha described from the same. The *Lebiini* are more varied and abundant: Motschulsky has credited two extinct genera, Agatoides and Cymindoides, to amber, besides which Dromius and Cymindis are reported from the same; species of Cymindis are also described from Oeningen and the Pennsylvania bone caves, and of Lebia from Salzhausen. Among the *Platynini*, a species of Platynus has been found in Wyoming, another in the Quaternary beds of La Boisse, and a recent species, *P. gracilis* Gyll., in the Pleistocene of Jarville. Heer has found an Anchomenus at Radoboj and Menge recognizes it in amber, which also harbors Calathus. Of the *Licinini*, five species of Badister occur at Oeningen, Horn finds two of Dicælus in the Quaternary bone caves of Pennsylvania, and Wollaston recognizes Licinus in the Lexden peat. The *Pterostichini* are still more varied: three species of Pterostichus are known from Oeningen and the peat of Wohlscheid, and it has also been noticed in amber and in the Pennsylvania bone caves; two species of Argutor are described from Oeningen, and a recent species, *A. vernalis*, in the interglacial clays near Basel; another recent species, *Omaseus nigrita*, occurs in similar beds at Dürnten; two species of Feronia are described from Aix and one is said to occur in the Pleistocene of Utznach; four species of Amara occur at Oeningen and Hochheim, one of Stomis at Aix, and a Loxandrus in the glacial clays near Toronto, Canada. Among the *Pogonini* we have two species of the extinct genus Trechinites at Oeningen. Motschulsky recognizes another extinct type, Trechoides, in amber, and Fliche finds the recent *Patrobus excavatus* in the Pleistocene of Jarville. Of the *Bembidiini* only Bembidium has been found, but of it four species, in amber, in Wyoming, and at Aix, besides the recent species, *B. nitidulum* and *B. obtusum*, in peat at Jarville. A species of Panagæus, found at Aix, represents alone the *Panagæini*. When we come to the *Carabinæ* proper we find among the *Scaritini* an interesting extinct type, Glenopterus Heer, represented by a single species at Oeningen; Heer also describes a Scarites from Radoboj and Clivina occurs in amber. The *Nebriini* are represented by Nebria, which has one species each at Oeningen, Aix, and in British Columbia, and has been detected also in amber. A single

Loricera from the glacial clays of Toronto, Canada, represents the *Loricerini*, and three species of Cychrus, described from the Pennsylvania bone caves and from Wyoming, the *Cychrini;* while for the *Carabini* no less than ten species of Calosoma are described from Aix, Oeningen, Locle, and the Rhine, eight species of Carabites from the polar regions, Oeningen, and Dürnten, and a recent species of Carabus, *C. arvensis*, is found at Schwerzenbach; the genus has also been recognized in amber. Other undetermined species of Carabidæ have been reported from Antrim and Hérault, and some thirty species occur at Florissant.

4. Family **Cicindelidæ.**

Brullé reports a species of Cicindela in amber.

C.—METABOLA Packard (ex Leach).

Body generally small, cylindrical, distinctly triregional, and well constructed for swift or directed flight. Thorax highly organized and compact, the prothorax insignificant, the abdomen generally pedunculate. Mouth parts haustellate. Front wings membranous, generally larger, often much larger, than the hind pair, the veins generally distant and the membrane without reticulation. Metamorphosis complete; pupa inactive.

5. Order DIPTERA Linné.

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(See, also, pp. 32 and 36.)

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Body generally small, subcylindrical, sometimes flattened above, completely triregional, the head especially being connected with the thorax by a very constricted neck, the integument delicately coriaceous. Antennæ either long, filiform, and generally simple, or short, with the

third joint inflated and the remainder reduced to two or three tapering joints or a bristle. Mouth parts adapted for piercing and sucking, the greatly developed fleshly labium (which is destitute of palpi) serving as a gutter for the reception of the lancet-like maxillæ and mandibles. Prothorax reduced to at most a mere collar on the front of the mesothorax, which latter is developed at the expense of both the other parts of this region. Front wings membranous, never folded, generally slender, with an inferior basal lobe, the veins in front crowded, behind distant, the cross-veins few and definitely placed; no reticulation. Hind wings reduced to a club-shaped lamina. Legs very slender. Metamorphosis complete, the appendages of the pupa free, but the whole pupa often undergoing its transformation within the larval skin. These metamorphoses are characterized as orthorhaphic when the pupa escapes by a T-shaped vent in the larval skin and cyclorhaphic when it escapes through a circular opening forming a lid. Corresponding exactly to this and to structural distinctions in the wings, the larva, which is apodal or vermiform, is either acephalous, the first segment never being chitinous (Cyclorhapha), or has a more or less perfectly developed head (Orthorhapha).

1. Division DIPTERA CYCLORHAPHA Brauer.

The only Mesozoic species (excepting a couple of Syrphidæ) referred to this division of the Diptera, and possibly belonging here, is *Musca lithophila* from Solenhofen, an object so obscure that it is not even certainly a Dipteron.

In the Tertiary rocks this division is much more rare than the other Diptera, and, with the exception of the Syrphidæ, may be treated as a whole.

Four species of Musca, using the term in a broad sense, are described by Presl from amber, and Schlotheim, Burmeister, and Gravenhorst also refer to it in the same way. Larvæ of this division, under the names of Musca and Muscidites, are described from Utah and from the Rhine. A vast host of undetermined genera of several of the families occurs at Florissant. Our present knowledge, however, is largely dependent upon amber. To take the series of families in their natural order, we may begin with the *Phoridæ*, where Loew has recognized eleven species of Phora in amber, some of them differing greatly from modern forms; of the *Agromyzidæ*, a species of Agromyza has been found at Radoboj and a larval mine on Ulmus at Schossnitz has been referred to the same genus by Göppert; of the *Oscinidæ*, Chlorops occurs in amber; of the *Drosophilidæ*, Drosophila, in amber; of the *Ephydridæ*, Ochtera at Aix and Ephydra in amber; of the *Sapromyzidæ*, Sapromyza in amber; of the *Lonchæidæ*, one species each of Palloptera and Lonchæa, described from British Columbia; of the *Trypetidæ*, one species of Tephoritis from Radoboj; of the *Ortalidæ*, an extinct genus Lithortalis from British Columbia (eight

or ten species of this or the preceding family occur at Florissant); of the *Micropezidæ*, Calobata (two species) in amber; of the *Psilidæ*, an extinct genus Psilites described from Radoboj; of the *Sciomyzidæ*, three species of Sciomyza described from British Columbia; of the *Helomyzidæ*, two species of Heteromyza described, one from Utah and one from Wyoming, and Helomyza recognized in amber; of the *Cordyluridæ*, Scatophaga in amber, Cordylura at Radoboj; perhaps also Heer's *Dipterites obsoletum* belongs here (Massalongo's *Dipterites Angelinii* from Monte Bolca is quite unintelligible); of the *Anthomyidæ*, six species of Anthomyia described from Radoboj, Rott, and British Columbia, besides which Anthomyia and Etiphia have been found in amber and species of undetermined genera occur at Florissant; of the *Muscidæ*, Stomoxys is referred to by Giebel as occurring in the Tertiary (without specification) and Loew recognizes the family in amber; of the *Tachinidæ*, Tachina, Echinomyia, and undetermined genera in amber, and a species of Echinomyia described from Oeningen; of *Œstridæ*, Œstrus in amber and at Florissant, with possibly the larva from Oeningen described by Heer under the name of *Dipterites obovatum;* of *Pipunculidæ*, Pipunculus in amber and half a dozen species of the family at Florissant; of *Conopidæ*, an extinct genus, Poliomyia, has been found in Wyoming, and a second, unnamed, has been briefly characterized by Loew from amber.

Family **Syrphidæ.**

A very obscure object from Solenhofen is referred by Weyenbergh to Cheilosia, and Giebel refers to a new genus, Remalia, a minute fly figured by Brodie from the English Purbecks, but its reference here is very doubtful.

In the Tertiaries this family is more abundant and varied than any of the other families of Diptera cyclorhapha. Burmeister and Serres both recognize Microdon at Aix, Pipiza has been described from Rott, Cheilosia from Wyoming, and seven species of Syrphus from Oeningen, Radoboj, Rott, and Sinigaglia, besides which it has been recognized in amber. In amber, also, are found two peculiar genera allied to Oscia and Xylota, besides Cheilosia, Volucella, and Criorrhina; Rhingia is noticed at Aix, Eristalis described from Utah, Helophilus and Merodon from the Rhine, and Milesia from Wyoming. Lastly some thirty or more species of various genera occur at Florissant, a considerable number of them in a remarkable state of preservation.

2. Division DIPTERA ORTHORHAPHA Brauer.

1. Section BRACHYCERA Zetterstedt.

1. Family **Dolichopodidæ.**

This family is particularly abundant in amber, Loew having counted not less than sixty-eight species of the genera Dolichopus, Rhaphium,

Porphyrops, Psilopus, Medeterus, and Chrysotus. Giebel describes a single species each of Medeterus and Chrysotus from amber, and the genus Dolichopus has been recognized at Sieblos and in Wyoming and British Columbia.

2. Family **Empidæ.**

Weyenbergh figures a fly from Solenhofen under the name of *Empidia Wulpii* and a species from the Wealden of England figured by Brodie is referred by Giebel to a new genus, Hasmona.

All but one of the twelve genera which have been recognized from the Tertiaries are known from amber. Of the *Tachydromina* we have three species of Hemerodromia, five of Tachypeza, seven of Tachydromia, and one of Drapetis recognized by Loew in amber. Of the *Empidina* proper, Loew found twenty-one species of Rhamphomyia, sixteen of Empis, three of Leptopeza, three of Gloma, and two of a genus near Hilara, all from amber; besides which Giebel describes two species of Empis from amber and two are described from the Rhenish coal; the genus has been recognized also at Aix and Heer describes an extinct genus, Hilarites, from that place. Of the *Hybotina* all again are amber species, Loew recording two species of Hybos and one of Brachystoma, while Giebel describes a species of Thirza.

3. Family **Cyrtidæ.**

A species of Acrocera is described from Utah.

4. Family **Therevidæ.**

One species of Thereva is described from the Rhine and three were recognized by Loew in amber.

5. Family **Bombylidæ.**

The only species known to Loew from amber was a Corsomyia, but Giebel describes a Lomatia and Burmeister mentions an Anthrax from the same. Anthrax is also said to occur at Oeningen and on the Rhine and Germar describes an Anthracida and a Phthiria from the Rhine. Berendt also recognized Bombylius in amber and Schlotheim says it occurs at Oeningen. Florissant has a great variety of forms of this family, though the species are rare in individuals.

6. Family **Nemestrinidæ.**

Serres mentions a Nemestrina at Aix, and a new genus, Palembolus, is described from Florissant, which has, besides, several other species belonging to this family or to Midaidæ.

7. Family **Asilidæ**.

This family is represented in the Mesozoic rocks by an insect in the Lower Lias of Forthampton, Eng., referred by Brodie to Asilus, and by one from the Oölite of Solenhofen, called Asilicus by Germar.

In the Tertiaries we have five species of Asilus described from amber, Oeningen, and Radoboj, besides which it is reported from Aix and Rott; of the section *Dasypogonina* there is an extinct genus, Stenocinclis, found in Wyoming. Holopogon has an amber species and Leptogaster one at Radoboj; Dasypogon also is reported as found in both Prussian and Sicilian amber. This family and the following are abundantly represented at Florissant, and the former also occurs in British Columbia, and, according to the author of the Ittiologia Veronese, in Italy.

8. Family **Leptidæ**.

Atherix and Leptis are the only genera of this family described as fossil; of the former four species were known to Loew from amber, of the latter five, and, besides this, it has been recognized by F. Smith in the Eocene deposits of the Isle of Wight.

9. Family **Tabanidæ**.

This family is rare in a fossil state. Loew found but a single specimen in amber, belonging to Silvius, and it has not been otherwise reported from that source. Heer figures a species of Hexatoma from Oeningen. Aymard referred an undescribed species from Le Puy to a distinct genus, Æmoaipus. Tabanus has been reported to occur in the Rhenish coal and at Aix and Malfatti finds a specimen referred to this family in the calcareous tufa of the Quaternary of Grone, Italy.

10. Family **Acanthomeridæ**.

A single specimen of a species of Arthropeas was found by Loew in amber.

11. Family **Stratiomyidæ**.

The larger part of the fossil species of this family have been recognized at Aix, where Giebel describes a new genus, Curtisimyia, and Hope figures an Odontomyia. Serres also recognized there species of Nemotelus, Oxycera, and Sargus. In addition to these, Oustalet describes a species of Stratiomys from the Miocene of Pontary, and the same genus has been recognized in larvæ at Bernouville (Quaternary) and at Rott, and Beris by Giebel at an unmentioned Tertiary locality. At Florissant there are a half dozen species of different genera.

12. Family **Xylophagidæ**.

Loew found in amber a large species of Xylophagus, two species of a new genus (Bolbomyia), one species of still another extinct genus (Habro-

soma), and one species each of Electra and Chrysothemis; most of them are known by single examples. Heer also describes a Xylophagus from Aix, where Serres had already recognized its presence.

2. Section NEMATOCERA Latreille.

1. Family Rhyphidæ.

A very fragmentary fossil from the English Purbecks is figured by Brodie under the name of *Rhyphus priscus*, but is referred by Giebel to a special genus, Bria. It is doubtful whether it belongs here; it is indeed more probably a Chironomid.

The family is recognized in Tertiary times by four species of Rhyphus credited by Loew to amber, by the occurrence of the same genus in Sicilian amber according to Guérin, and by a species of the same described by Heer from Radoboj.

2. Family Tipulidæ.

Several species of Tipulidæ are referred to by Brodie, Westwood, Buckman, and Murchison as found in the Lias and Purbecks of England, but in some instances where they are figured they certainly belong to other families of Nematocera. One doubtful species, called *Tipularia Teyleri*, has been recognized by Weyenbergh in the Oölite of Solenhofen.

In the Tertiary beds no family of Diptera has attained such variety, although the number of individuals found has not been so large as, for instance, in the Bibionidæ. It is also peculiarly rich in extinct genera.

Of the Tipulidæ with short palpi we have a large number recognized by Loew in amber; such are: Rhamphidia, 4 sp.; Elephantomyia, 3 sp.; Cylindrotoma, 4 sp.; Trichocera, 2 sp.; Eriocera, 2 sp.; and Erioptera, 14 sp.; besides the following extinct genera peculiar to amber: Trichoneura, 3 sp.; Calobamon, 1 sp.; Haploneura, 4 sp.; Critoneura, 2 sp.; Tanymera, 4 sp.; Tanysphyra, 1 sp.; Ataracta, 8 sp.; and Styringomyia, a genus also found in copal, 1 sp.; in addition Giebel describes two species of Limnobia in amber and it has been recognized by a dozen other species at Radoboj, Aix, Oeningen, and on the Rhine; Erioptera also has one species at Rott and Trichocera one at Aix; in addition to which we have, of genera not represented in amber, a Rhipidia at Radoboj and three species of Dicranomyia in Utah; Utah also furnishes three extinct genera, Cyttaromyia, Spiladomyia, and Pronophlebia, with one species each. At least fifteen or twenty species of this group have been found at Florissant.

Of the other Tipulidæ Loew found in amber sixteen species of Tipula, one of Macrochile, and four of Dixa; Berendt reports also Adetus. Tipula has also been found abundantly in other places, about eleven species having been described from Radoboj, Aix, Krottensee, Italy, and Utah, besides having been mentioned from Sicilian amber and as

a larva at Sieblos. Nephrotoma has also been credited to Aix by Serres, Ctenophora described from Rott, and Ptychoptera from Krotten see. This division has been found in still greater abundance than the other at Florissant and is even richer in individuals. The family is also recognized by H. Woodward in the Eocene deposits of the Isle of Wight and Aymard records two species of an extinct genus at Le Puy.

3. Family **Psychodidæ.**

This family is known in a fossil state only from amber, in which Loew has found eighteen species, a number which he thinks may be reduced by more abundant material. Six species of the existing genus Psychoda are recognized, while the other genera are all peculiar to amber, Phalænomyia with nine species, Diploneura with two, and Posthon with one species. Psychoda was also recorded among amber inclusions by Burmeister.

4. Family **Chironomidæ.**

One would scarcely expect the delicate, minute flies of this family to be preserved from Mesozoic times, yet they seem to be not altogether unknown. Two species referred to Macropeza are figured, one by Geinitz from the Lias of Dobbertin and one by Brodie from the English Purbecks; two other obscure forms from the English Purbecks are figured under the name of Chironomus; and *Corethrium pertinax* and *Cecidomium grandævum* of Westwood, from the same beds, appear to belong to this family rather than to the Cecidomyidæ or Culicidæ. *Rhyphus priscus* Brodie, from the English Purbecks, also probably belongs here and not to the Rhyphidæ.

The family is very abundant in amber, Loew having found seven species of Tanypus, more than forty of Chironomus, and twenty-six of Ceratopogon. Giebel also describes two species of Chironomus and one of Ceratopogon from amber, and these genera had previously been recognized as occurring there by Burmeister, Erichson, and others. Duisberg also records a peculiar genus, Sendelia, from the same. But the occurrence of the family in a fossil state is not confined to amber: thirteen species of Chironomus have been described from Rott, Oeningen, Radoboj, and Utah, and the genus has been recognized also in Wyoming, while numerous pupæ distinguishable as belonging to several species are recorded by Heyden from Rott. Ceratopogon has also a species at Rott, and it has been recognized at Aix and in Sicilian amber. Numerous specimens of the family occur at Florissant, but they are usually in very poor condition; they have also occurred in the British Columbia Tertiaries.

5. Family **Culicidæ.**

The English Purbecks have furnished two species which have been referred to this family, one a very obscure object, called *Tanypus dubius*

by Brodie, but referred to a new genus, Asuba, by Giebel; the other, a wingless specimen, but with antennæ and legs preserved, called *Culex fossilis* by Brodie.

The only members of this family found by Loew in amber are a species of Mochlonyx and one of Culex; Giebel also describes a species of Culex from amber and species have been described from Rott and from Utah. Heyden also describes another species from Rott, under the name of Culicites, a Corethra is described from Utah, and one is mentioned from Aix. Two or three species only of this family in single examples are found at Florissant and it has been recognized in the Isle of Wight Tertiaries.

6. Family Bibionidæ.

Although species supposed to belong to this family have been reported from Mesozoic rocks, it is doubtful whether it is yet recognizable before Tertiary times. *Protomyia dubia*, figured by Geinitz from the Lias of Dobbertin, is certainly not a Dipteron at all.

In Tertiary times, however, they are among the commonest of insects, as far as individuals go, though they are not correspondingly rich in species, and in amber they are comparatively rare, the genera most abundant in the rocks being almost or altogether absent. The species found by Loew in amber are one of Dilophus, two of Plecia, and three of Scatopse. Bibio is also reported from amber by Guérin, Serres, and Burmeister, but they probably mistook some other genera for Bibio or used the term in the broad sense of the family, since Loew says it "appears strangely enough to be altogether wanting." Of these genera, Dilophus and Plecia[1] occur in the rocks, the former in a single species at Rott and indicated only at Aix (Serres), the latter in considerable abundance, for over twenty species are described from Oeningen, Radoboj, Aix, Rott, Parschlug, Corent, Auvergne, Krottensee, Wyoming, and British Columbia, while an allied extinct genus, Epiplecia Giard, occurs at Corent; Bibio is even more numerous, over forty species having been described from Oeningen, Rott, Corent, Aix, Radoboj, Wilhelmsfund, Krottensee, Tállya, Felek (near Klausenburg), and Monte Bolca; and Bibiopsis,[1] an allied extinct genus, has five species from Salzhausen, Krottensee, Aix, and Rott. Another extinct genus, Protomyia,[1] has nearly forty species at Oeningen, Aix, Krottensee, Corent, and Rott, while Penthetria has four species at Radoboj and Corent, besides being recognized at Aix and Krottensee. Fully one thousand specimens of this family have been found at Florissant, but the species are not correspondingly numerous, being apparently but fifteen or twenty in number.

[1] The species first referred to Protomyia and Bibiopsis by Heer, who founded the genera, are not included under these names in this enumeration, since Loew considered them all to belong to Plecia and the genera as without foundation. Those since published have not been critically examined. *Penthetria similkameena* Scudd., from British Columbia, is a Plecia.

7. Family Simulidæ.

The Purbecks of England furnish two species, *Simulium humidum* Brod. and *Simulidium priscum* Westw., apparently belonging to this family.

In the Tertiaries the genus Simulium has been recognized in a species described from Rott by Heyden, in six species recorded by Loew from amber, and in one found by Guérin in Sicilian amber.

8. Family Mycetophilidæ.

In the Mesozoic this family is represented only in the English Purbecks. Here we recognize species figured by Brodie under the genera Platyura, Macrocera, and Sciophila, and credited by Giebel to new genera, Adonia, Sama, and Thimna, respectively; also a second Sciophila, which is very obscure, and a species figured by Westwood, which Giebel refers to an extinct genus, Thiras!

In the Tertiaries this family is one of the best represented and is abundant in generic types, though, as compared to the Tipulidæ, few of these are extinct. The greater number have been found in amber, and, as in the Bibionidæ, such as have been found in the rocks belong generally to genera distinct from those occurring in amber. The following genera have been found in amber by Loew: Zygoneura, 1 sp.; Sciara, 21 sp.; Mycetophila, 23 sp.; Leja, 26 sp.; Sciophila, 15 sp., besides 3 described by Giebel; Sciobia, 19 sp.; Platyura, 16 sp.; Macrocera, 6 sp.; Heterotricha, 1 sp.; Dianepsia, 2 sp.; Mycetobia, 5 sp.; Aclada, 2 sp., and Diadocidia, 1 sp. Boletophila is also reported in amber by Burmeister and four of the genera mentioned above have been found in the rocks, viz: Sciara, of which twelve species have been described, from Aix, Radoboj, Oeningen, Rott, Krottensee, and British Columbia, besides mention of several other species at these same places; Mycetophila, fifteen species, from Radoboj, Aix, Oeningen, and Utah, besides other unnamed species from Aix and Auvergne; Sciophila, one from Parschlug; and Diadocidia, one from Green River. Of the genera above mentioned, four are peculiar to amber, Sciobia, Heterotricha, Dianepsia, and Aclada; and an extinct genus, Sackenia, has been found in Utah. Further than this, five species of Cordyla and one of Boletina are known from Rott, two of Brachypeza, one of Trichonta, and one of Boletina from British Columbia, and one of Gnoriste from Utah, the last being also indicated from Aix. Species of undetermined genera have also been reported from Sicilian amber, Rott, Wyoming, and Florissant, in the last of which more than thirty species have been found.

9. Family Cecidomyidæ.

Our knowledge of this family also is largely due to amber. In the *Anaretina* the only genus found by Loew is Campylomyza, of which he

records five species. An extinct genus, Lithomyza, is, however, described from Utah, apparently belonging to this section. Of the *Cecidomyina*, Loew found the extinct genus Monodiciana, with one species in amber, together with eighteen species of Cecidomyia, distributed among the subgenera Diplosis, Cecidomyia, Dirhiza, Epidosis, and Synapta. Lasioptera was also recognized in amber by Burmeister and has been described from Wyoming, while three species of Cecidomyia have been described from Oeningen, Rott, and Aix, and recognized also in Sicilian amber.

6. Order **LEPIDOPTERA** Linné.

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Body cylindrical, elongated, completely triregional, the integument delicately coriaceous. Antennæ long, filiform, and, excepting sometimes for regular, lateral, laminate outgrowths, simple. Mouth-parts arranged for sucking, the greatly elongated maxillæ forming a hollow canal by the union of their channeled inner surfaces and capable of rolling up like a watch spring between the appendages of the labium; mandibles aborted. Pronotum insignificant, but distinct from the compact thorax, which is composed subequally of the other two joints. Wings subequal; generally very large, membranous, the hinder pair sometimes folded slightly at the inner edge, covered on both surfaces with imbricated and colored scales, often forming patterns of exquisite beauty; the neuration simple, the marginal vein absent, the scapular and externomedian united or approximated in the middle of the wing forming between them a median cell and furnishing almost all the subordinate branches; cross-veins almost wholly wanting; no reticulation. Legs very slender. Metamorphosis complete; the appendages of the pupa soldered to the body. Larva eruciform. Habits terrestrial, but many larvæ endophytophagous, and the pupæ generally concealed or inclosed in a loosely-woven cocoon.

The fossil forms of this order are so rare that they may be treated here in a single paragraph. All such as have been credited to Carboniferous deposits have been shown to belong to other groups. The Mes-

ozoic forms are exceedingly few. The mines of Tineidæ or allied moths have been noticed by Fritsch in leaves from the Cretaceous of Bohemia and by Hagen in some from the Dakota group of Nebraska. *Tineites lithophilus* Germ., from the Oölite of Eichstatt, is, according to Heer and Hagen, a Termes. Two Sphingidæ, *Sphinx Snelleni* and *Pseudosirex Darwini*, have been described by Weyenbergh from the Oölite of Solenhofen. The former is represented by a very characteristic fossil in which the spiral tongue appears; the latter, by a far more obscure wing.

In the Tertiaries these insects are more common, but still among the greatest rarities. All the larger groups, however, are represented. Among the *Microlepidoptera* the *Tineidæ* are not rare in amber, Menge having sixty-nine specimens in his collection, of which one was a caterpillar and two were pupæ, but they have not been studied. Gravenhorst also mentions a Tinea in amber and Presl describes one species. Germar figures an Ypsolophus from Bonn and Heyden the larval mine of a Nepticula from Rott. Kawall also describes a Tineites from Bergkrystall at Ufalei, in Siberia. The *Tortricidæ*, too, occur in amber, Menge having fifteen moths, seven larvæ, and four pupæ of several species. The *Pyralidæ* are represented by a single specimen from Aix, which Heer describes under the name of Pyralites. Of the *Phalænidæ*, Heer describes two species referred to Phalænites from Radoboj and mentions one from Aix, and Curtis mentions one from the latter place, which, however, he says may be a noctuid. Giebel also describes an Angerona from amber, on the wing of which he noted two specimens of a species of Chelifer. Of the *Noctuidæ*, four species, some of them exceedingly obscure, have been described under the name Noctuites, two from Radoboj, one from Aix, and one from Auvergne. *Bombycidæ* are more numerous. Two species of Bombycites are figured by Heer from Oeningen, together with the larval sac of a species of Psyche. The latter group has been recognized in the same way in amber, Menge mentioning fifteen larval sacs of seven different kinds. A species of Lithosia is said to be found at the Isle of Wight and Serres refers species at Aix to Bombyx or Cossus and to Zygæna. Of the *Sphingidæ*, Berendt says that a Sphinx occurs in amber and Serres refers to two species of Sesia at Aix. The *Rhopalocera* are first known to us in the Tertiaries, all references to their earlier appearances having been shown to be erroneous, and more than a dozen species are recorded, belonging to as many genera, most of the latter extinct. Of the existing genera we have only two, a Pontia and a Eugonia at Radoboj, which also furnishes a species of Mylothrites. Aix furnishes the largest number (5), Pamphilites, Thaites, Coliates, Lethites, and Neorinopis, besides a larva described by Daudet under the name Satyrites; Florissant, the next largest (3), Prodryas, Jupiteria, and Lithopsyche, all nearly related, besides one or two other undetermined forms. Rott gives us Thanatites, and a second species is reported from the same place, but not yet described. According to Gravenhorst,

the larva of a Lycæna occurs in amber. Finally, Procaccini Ricci states that Lepidoptera have been found at Sinigaglia.[1]

7. Order HYMENOPTERA Linné.

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Body completely triregional, subcylindrical, the abdomen sometimes depressed or compressed, both head and abdomen generally connected with the thorax by a constricted neck, the integument subcorneous. Antennæ simple, filiform. Ocelli generally present. Mouth-parts arranged for lapping, in which the highly-developed and greatly-elongated labium and its appendages perform the principal part, ensheathed loosely by the maxillæ; the mandibles are also well developed, but principally as weapons or tools in the economy of the insect. Pronotum small, but generally fused with the rest of the very compact thorax, in which the mesothorax largely predominates. Wings membranous, slender, the front wings much larger than the hind pair and sometimes folded once longitudinally; both with few and rather distant veins, which

[1] Since this was written Dr. Oppenheim, of Berlin, has published an important paper dealing mostly with Mesozoic Lepidoptera (Die Ahnen unserer Schmetterlinge in der Sekundär- und Tertiärperiode. Berl. entom. Zeitschr. Band XXIX. Pl. 10–12. 1885). Eight species are described and figured. Two of them, from the Brown Jura of Siberia, belong to one type and are considered as nearly related to Cossus and Phragmatœcia. The neuration, as figured separately on the plate, appears, however, to differ in important particulars from the excellent figures of the original fossils given beside them. They are named *Palæocossus jurassicus* and *Phragmatœcites Damesii*. The others all come from the White Jura of Solenhofen and include not only such as had before been referred to Sphinx, but also *Belostomum elongatum*, which, following Assmann, has in this essay been placed under Hymenoptera; they form a very distinct type, which, in all respects but the neuration of the wings, reminds one strongly of the Sphingidæ. This exception is, however, a marked one and forbids their being looked on as Lepidoptera in a strict sense. Dr. Oppenheim has therefore considered them as forming a distinct order, giving them the name of Rhipidorhabdi. They are referred to the genera Rhipidorhabdus and Fabellovena, with three species each. It remains to be seen how close the relationship may prove to be between these Rhipidorhabdi and the Jurassic species from Siberia. It looks as though it were closer than Dr. Oppenheim indicates.

often do not reach the outer margin of the wing and beyond the middle are usually connected by cross-veins to form rather large polygonal cells; sometimes nearly all the veins are aborted; no reticulation. Legs very slender. Abdomen frequently furnished with an exserted, needle-like, complex sting or ovipositor. Metamorphosis complete, the appendages of the pupa free. Larva of two types, eruciform and vermiform, corresponding to structural distinctions in the imago. Habits terrestrial, but many of the larvæ inhabit galls or are parasitic in the larvæ of other insects, and the pupæ are generally inclosed in a dense silken cocoon. The order comprises the most highly organized and complex social communities among insects.

The number of Hymenoptera which have been found in Pretertiary deposits is so small that it will be best to consider them in a single paragraph. Eight or ten species only are known, most of which have been described from Solenhofen and are generally very obscure objects, of which little more can be said than that they are probably Hymenoptera. Such are two species of Apiaria described by Germar and by Weyenbergh, though Assmann considers *Apiaria antiqua* to be a Sirex and *Apiaria lapidea* the same as Germar's *Carabicina decipiens*. Two others are looked upon by Assmann as Uroceridæ, namely, *Belostomum elongatum*[1] and *Sphinx Schroeteri* of Germar. *Bombus conservatus* Weyenb. presents no tangible characters, and it is impossible to say whether his *Anomalon palæon* is a Hymenopteron or not. The other Mesozoic species are in better state of preservation and, excepting the eggs of a Nematus (one of the Tenthredinidæ) figured by Fritsch from the Cretaceous of Bohemia, are all Formicidæ. One of the oldest Hymenoptera known comes from the Lias of Switzerland and was figured by Heer under the name of *Palæomyrmex prodromus;* the other two are from the English Purbecks and were figured by Westwood under the name of *Formicium Brodiei* and *Myrmicium Heeri.*

1. Tribe TEREBRANTIA Latreille.

1. Family Tenthredinidæ.

This family has been found in only one or two localities in Tertiary deposits and is very rare in amber, single specimens of a winged Cephus and Emphytus and of larval Cimbex, Lyda, and Lophyrus having been reported by Menge. Gravenhorst and Schlotheim also state that Tenthredo is found in amber. Curtis reports the latter genus also from Aix, as does Serres, together with species of Pteromus and Cryptus. Besides this, Heer describes two species of Cephites from Oeningen and two of Tenthredo from Oeningen and Aix. On the other hand, considerable numbers have been found at Florissant, some seventy specimens having occurred, of at least twenty species.

[1] See note on p. 96.

2. Family Urocerida.

The only Tertiary fossils of this family known are a species of an extinct genus, Urocerites, described by Heer from Radoboj, and an undescribed species from Florissant. (For probable Mesozoic forms, see the preceding page.)

3. Family Cynipidæ.

Gravenhorst states that Diplolepis occurs in amber, from which deposit Presl describes a species of Cynips. Menge also states that the family is found in amber, but in scanty numbers. Heyden refers doubtfully to Cynips or Pteromalus some mines in leaves of Juglans from Salzhausen. The family is very abundant at Florissant, and two or three galls have been obtained there.

4. Family Pteromalidæ.

This family is much more abundant in amber than the preceding, Menge mentioning forty-eight specimens in his collection. It occurs also at Florissant, and Heer refers under the name Pteromalinites to a species at Oeningen. None whatever have been described.

5. Family Chalcididæ.

Of this family Heer describes a species of Chalcites from Aix and Scudder one of Decatoma from Wyoming. Chalcididæ occur at Florissant in some abundance, at least four or five species and twenty specimens having been obtained.

6. Family Proctotrupidæ.

This family of minutest insects is known only from amber. Burmeister and Gravenhorst report Ceraphron and Psilus as occurring in the Prussian amber, and Myrmar, that mere speck, is figured by Duisburg from Prussian and by Malfatti from Sicilian amber.

7. Family Braconidæ.

Two species of Bracon have been described from Sieblos and Wyoming, and an extinct genus, Calyptites, from British Columbia. Bracon is also said to occur at Aix and in British Columbia, as well as in Prussian and Sicilian amber. Gravenhorst says that Chelonus also occurs in amber and Serres credits a species of Agathis to Aix. Many specimens of this family have been found at Florissant.

8. Family Ichneumonidæ.

This family is well represented in Tertiary deposits, though no great number have yet been described. Most of these have been published

under the generic names Pimpla and Ichneumon, the former being represented by seven species, from Aix, Radoboj, amber, and British Columbia, and the latter by four, from Aix, Oeningen, Radoboj, and Utah, besides which there are references to others in amber and at Aix. Heer, also, under the generic name Ichneumonites, describes one species each from Oeningen and Radoboj, suggesting that the one from the latter place may be a Trogus. From Radoboj come also single species of Acœnites and Hemiteles, and from Oeningen, of Anomalon and Cryptus, both of which are also reported from Aix and the latter from amber. Ophion is stated to occur at Aix, and that or Campoplex in the Quaternary of Pianico in Italy. At Florissant this family is remarkably well represented, hundreds of specimens occurring, with a remarkable variety of species and genera.

9. Family **Evaniidæ.**

Burmeister recognized Evania among amber insects.

2. Tribe ACULEATA Latreille.

1. Family **Formicidæ.**

That this family was an ancient one and represented to some extent in Mesozoic times may be seen above (p. 97). No other family, not only of Hymenoptera but even of any Hexapoda, was so abundant in Tertiary times, whether in species or in individuals. At Florissant they comprise, in individuals, about one-fourth of all the insects, and more than four thousand specimens have already been brought from that locality. Mayr has carefully studied nearly fifteen hundred specimens from amber, in which he has detected forty-nine species of twenty-three genera. More than one hundred and seventy species have been described from different localities, but by far the largest number from amber and Radoboj, and thirty-four or more genera are recognized. Of these the largest number of species belong to the *Formicidæ* proper; of genera, to the *Myrmicidæ*.

Of the latter subfamily Mayr finds three extinct genera in amber, namely, Stigmomyrmex with two species and Enneamerus and Lampromyrmex with one each. Heer describes four Radoboj species under the new generic name Attopsis, which Mayr finds is the same as the existing but later founded genus Cataulacus. Heer also describes a fragment from Spitzbergen under the generic name Myrmicium. Mayr describes a species of Lonchomyrmex from Radoboj, which Assmann finds also at Schossnitz. Besides these the Prussian amber has furnished the genera Aphænogaster, 2 sp.; Macromischa, 4 sp.; Myrmica, 2; Leptothorax, 1 sp.; Monomorium, 1; Pheidologeton, 1, and Sima, 3 sp. Of these Aphænogaster possesses four other species from Oeningen, Radoboj, and British Columbia; Myrmica, no less than twelve other described species from Oeningen, Radoboj, Parschlug, and Krottensee, and is recorded

from the Isle of Wight; Leptothorax has another species at Radoboj; and Pheidologeton has two others, from Schossnitz and Krottensee. A species of Crematogaster also occurs at Radoboj, with one of Pheidole and one referred doubtfully to Solenopsis, while Guérin figures two species of ants in Sicilian amber, which Erichson refers to Pseudomyrme.

Of the *Poneridæ* we have twenty-seven species, belonging to seven genera, of which the greater part are accounted extinct, viz: Bradoponera and Prionomyrmex from amber, with one species each; Imhoffia, with two species from Oeningen; and Poneropsis, with a dozen species from Radoboj and Oeningen. Besides these, amber has furnished, according to Mayr, Ponera with two species and Ectatomma with one, while F. Smith refers one he has seen to Anomma. Ponera is also represented in the rocks, having seven species in the deposits of Radoboj, Oeningen, and Parschlug.

Over one hundred species of *Formicidæ* proper are described, but only two of the genera are accounted extinct, Gesomyrmex and Rhopalomyrmex, each with one species from Prussian amber. This deposit has also furnished Camponotus, 3 sp.; Œcophylla, 1 sp.; Prenolepis, 2 sp.; Plagiolepis, 5 sp.; Lasius 4, sp.; Formica, 13 sp. (only 1, however, recognized by Mayr); and Hypoclinea, 8 sp.; besides, according to F. Smith, a Polyrhachis; while Malfatti figures a Tapinoma from Sicilian amber. Of these genera, Camponotus has six other species or varieties, found at Radoboj, Oeningen, and in Utah, and has, besides, been recognized in the Isle of Wight Eocene; Œcophylla has another species, occurring both at Radoboj and Kutschlin; Lasius, eleven species, at Radoboj, Schossnitz, and Wyoming; Hypoclinea, five others, from Radoboj, Kütschlin, and British Columbia; while Formica possesses no less than thirty-four species from various parts of the continent of Europe, but mostly from Radoboj and Oeningen, and one from British Columbia. Besides this, the genus has been recognized in Sicilian amber and at the Isle of Wight. Finally, four species of Liometopum are known from Radoboj and Utah.

2. Family **Chrysididæ**.

Giebel describes a species of Chrysis from amber, and at least one species, with the metallic-green reflections of the abdomen still remaining, occurs at Florissant. A species of Cleptes is mentioned by Beck as occurring in the Pleistocene deposits of Jutland.

3. Family **Mutillidæ**.

Menge found half a dozen specimens of this group in amber, previously reported to occur therein by Brongniart.

4. Family **Scoliadæ**.

Heer describes a Scolia from Oeningen and the family occurs at Florissant.

5. Family **Pompilidæ**.

Oeningen furnishes a species of Pompilus; Pepsis occurs, according to Burmeister, in amber; and the group is represented among the Florissant species.

6. Family **Sphegidæ**.

Heer describes a Sphex from Radoboj and two species of Ammophila from Oeningen. The latter genus is found at Florissant with other genera. In amber Menge found the family abundant, reporting sixty-nine species of *Crabronidæ* and twenty-two of other Sphegidæ, but no genera are mentioned by him.

7. Family **Vespidæ**.

Three species of Vespa are known from Radoboj, Parschlug, Moudon, and amber, and the genus is also reported from Aix. Polistes, of which one species is named from Oeningen, is also reported by Serres at Aix, by Latreille at Chaumerac, and by Scudder at Florissant, at which last place several other genera and a considerable number of species occur. Only three specimens of this family are reported in amber by Menge.

8. Family **Apidæ**.

This family was tolerably abundant in Tertiary times, to judge by the comparatively large number of fossil species known. Of the *Andrænidæ* mention is made only of their occurrence, rarely, in amber by Menge, who found two specimens of a genus allied to Dasypoda, and at Florissant, but the *Apidæ* proper are more numerous. From Oeningen and Radoboj, Heer describes five species of Anthophorites, and another comes from Corent, besides a species of Anthophora from Rott and one indicated from amber; seven species of Bombus, from Oeningen, amber, Radoboj, Rott, and Krottensee, besides one amber species referred by Motschulsky to Bombusoides; two each of Apis and Osmia, from Oeningen and Rott, besides an Apis from amber and an Osmia from Orsberg; finally a Xylocopa described from Oeningen and a Trigona said by Burmeister to occur in amber. A number of species of this family, mostly represented by single individuals and generally not very well preserved, occur at Florissant.

HISTORY AND DISTRIBUTION OF FOSSIL INSECTS.

Marcel de Serres's Géognosie des terrains tertiaires may be looked upon as the first general work on fossil insects. His fourth book, which treats wholly of insects, closes with a tableau général wherein one hundred and two genera of insects are enumerated, with two hundred and nineteen species. This work included the first general notice of the insects of Aix (nearly eighty genera being mentioned), which, had it not been published separately in advance, would have appeared, curiously enough, at the same time as Curtis's independent account of the insects of the same deposit (in which forty-seven species are enumerated). That year, 1829, may therefore well count as the starting point of our definite knowledge of fossil insects. In the following year appeared Berendt's first notice of the amber insects of his collection; but these were not carefully worked out, and then but partially, until twenty-five years later, previous to which epoch a marked increase in our knowledge and a widening of our horizon had been brought about by the publications of Germar and Goldenberg on the insects of the Coal Measures; of Brodie, Westwood, and Germar on those of the secondary rocks; and especially those of Heer (not to mention Heyden, Charpentier, and Unger) on the insects of Tertiary deposits. Since then contributions have been continually made, extending the field and introducing new elements of discussion, prominent among which may be mentioned the discoveries of Eugereon, Protophasma, and Palæoblattina in Europe and a vast store of Carboniferous and Tertiary insects in America.

About 1856 the number of fossil species was estimated by Bronn as a little more than 1,800 (7 Paleozoic, 126 Mesozoic, 1,682 Tertiary) and by Giebel as nearly 2,000 (21 Paleozoic, 231 Mesozioc, 1,744 Tertiary). At present it is probable that 2,600 species have been actually described or at least fully named (of which 155 are credited to the Paleozoic, 475 to the Mesozoic, and 1,972 to the Tertiary), a number which would be very largely increased, especially in the Tertiary insects, were we to include in our enumeration, as was done by Bronn and Giebel, those which had received generic indications only. The immediate future is likely

to bring the largest contributions to our knowledge from the Coal Measures of Commentry in France and the Tertiary tufa deposits of Florissant in America; although, since our knowledge of fossil insects is almost exclusively derived from Europe and North America, we cannot yet tell what to expect from other parts of the world.

The oldest known insect is *Palæoblattina Douvillei*, recently described by Brongniart from the Middle Silurian of France and of undetermined affinities. It is older even than the earliest known arachnids (Upper Silurian) or myriapods (Lower Devonian) and is followed at a considerable distance by the oldest insects of America (Upper Devonian). It is, however, only when we reach the productive Coal Measures that we arrive at insect faunas of considerable extent, such as those especially of Commentry in France and of Mazon Creek in Illinois. Other considerable deposits are found in the coal-fields of the Saarbrück and Wettin basins of Germany, the Belgian and British coal-fields, and in America the coal-basins of Nova Scotia and Pennsylvania. The Permian offers comparatively few species, but some of these are of particular interest (e. g., Eugereon), and the Trias is almost wanting in fossil insects, except in the South Park of Colorado, where about twenty species have recently been obtained, affording transitional forms among the cockroaches. Later Mesozoic deposits have yielded nothing in America, but much in England, where nearly all the strata from the Lower Lias to the Wealden have been productive. On the continent of Europe prolific Liassic deposits have been discovered at Dobbertin in Germany and Schambelen in Switzerland, while the oölitic beds of Solenhofen in Bavaria are world-renowned. Scanty returns have come from the Cretaceous, but the early Tertiaries have yielded an abundant harvest in the amber deposits of the Baltic shore, the marls of Aix, and in America at Florissant and Green River, while the Middle Tertiaries of Oeningen, Radoboj, Parschlug, Auvergne, and the Rhenish brown coal have been scarcely less prolific.

The relation between the Carboniferous insect faunas of Europe and North America (those of other continents are absolutely unknown) is by no means so close as in the case either of the arachnids or of the myriapods. While, for instance, the bulk of the fauna was in each hemisphere made up of cockroaches, one entire division of these (Mylacridæ), with five genera, was restricted to America and of the eight genera of the other division (Blattinariæ) only one-half (comprising, however, the most prolific genera) were common to both hemispheres; no identical species occur. In the other Paleozoic groups the difference is even more striking, the genera being rarely common to the two countries and whole series of forms being developed in one region which are completely wanting in the other, where they are replaced by an entirely different set. How far this statement of facts, based on present knowledge, may be modified when the insects of Commentry come to be known, it is, of

course, impossible now to say, but Mr. Brongniart[1] informs me that very few American types have been found there. Nevertheless one is struck by the common occurrence in the two hemispheres of such striking forms as Titanophasma and Megathentomum, and nearly all the families occur on both continents.

Our knowledge of Paleozoic insects dates back only a half century to the time (1833) when the wing of *Lithosialis Brongniarti*, from Coalbrockdale in England, was submitted to Audouin and reported upon by him to the French Academy of Sciences and elsewhere. He considered it a neuropterous insect allied especially to Corydalis and Mantispa. This and others closely allied to it have been variously interpreted by subsequent writers as neuropterous or orthopterous, and indeed, up to the commencement of Goldenberg's discoveries in the Saarbrück basin, hardly a score of Paleozoic insects being known, there were not sufficient grounds whereon to base an opinion concerning these ancient wings. His explorations and those following in their train have within the last ten years completely changed the aspect of the Paleozoic field and enabled us to obtain a more accurate picture of early insect life. This is mainly due, besides the mere abundance of material, to the discovery of two insects, Eugereon and Protophasma. The former, studied by Dohrn, possessed four similar, large, membranous, reticulated wings, like those heretofore classed as neuropterous, with prolonged mouth-parts, forming a rostrum similar to that now found in Hemiptera. The latter, studied by Brongniart, possessed wings which had up to that time been unhesitatingly described as neuropterous, attached to a body which was plainly that of a phasmid, one of the most peculiar tribes of Orthoptera. These generalized types have given a clew to the study of Paleozoic insects and have first rendered possible the discovery that there existed among these ancient forms no ordinal distinctions, such as obtain to-day, but that they formed a single homogeneous group of generalized hexapods, which should be separated from later types more by the lack of those special characteristics which are the property of existing orders than by any definite peculiarities of its own. Yet among the Paleozoic forms which by special characteristics can be claimed as the immediate progenitors of some existing families of insects, we find upon sufficient examination some fundamental structural features separating them as a whole from those of later times, separating them indeed more widely from them than from their nearest contemporaries. In one group, the cockroaches, where superficial observers claimed a very close agreement between ancient and modern types, it has been

[1] Mr. Brongniart has kindly sent me in manuscript an outline of his classification of Paleozoic insects, largely based on those found at Commentry, read at the Sorbonne in April, 1885; but as it consists of names only, and most of these are new, it is impossible to make use of it on this occasion excepting in the most general way. He recognizes five orders, fifteen families, and fifty-four genera, exclusive of the cockroaches. Thirty-eight of these genera and at least fifty-nine species are found at Commentry.

shown that their front wings alone differ in at least three important particulars from those of later times, and the passage between the ancient and modern types has been traced in the Triassic cockroaches of Colorado.

Every one of the existing orders of insects, however, is found in the middle of the Mesozoic period, and most of them in the early Mesozoic, full-fledged one might say, with a considerable development into existing families; and it is therefore presumable that, were the insects in general of Triassic times only as well known as are the cockroaches, we should be able to trace the differentiation of the ancient Palæodictyoptera into the existing orders of insects.

At present this is not possible, excepting by rather large presumption and on certain lines. Thus we can see that the modern cockroaches descended from the ancient, and it is highly probable that the Mantides were an offshoot from the same branch, possessing the same characteristic impression of the principal anal vein of the front wing. The ancient walking-sticks were evidently the precursors of the present Phasmida, although the wings and especially the front pair have little in common. It would seem not improbable that the saltatorial Orthoptera also originated from the Protophasmida. There can hardly be a doubt that the Palephemeridæ were the precursors of the existing May-flies, the Hemeristina were probably followed by the Sialina, and Fulgorina and Phthanocoris seem to have foreshadowed the Homoptera and Heteroptera respectively; but to what Eugereon led or the four families of neuropteroid Palæodictyoptera, called by me Homothetidæ, Palæopterina, Xenoneuridæ, and Gerarina, it is far more difficult to say. They appear to have about equal relations to the Perlina and Termitina among the Pseudoneuroptera and to the Sialina, Hemerobina, Panorpidæ, and Phryganidæ among the Neuroptera proper, while at the same time they are more nearly related to each other than are Fulgorina and Phthanocoris, indicating thus a greater antiquity for the separation on the one hand of the Homoptera and Heteroptera, and on the other of the Neuroptera as a whole and the Orthoptera, than for that of the Neuroptera vera and the Pseudoneuroptera, and rendering the separation of the last two as distinct orders unjustifiable on paleontological grounds, at least as long as all the Hemiptera are classed in one ordinal group. By thus tracing the probable genetic relation of Paleozoic to later types, we are able to distinguish among the former the outlines, or premonitions, as it were, of certain structural features, which afterward became fixed as peculiarities of one or another order, and in this way select from the more ancient forms such as may be distinguished as orthopteroid, neuropteroid, &c.

We have thus accounted for nearly all the principal existing groups of the lower hexapods, or Heterometabola, and we note, in passing, that as a general rule one common change has taken place in their wing structure in the passage from Paleozoic to later times. In all known

Paleozoic insects, excepting only Phthanocoris, the front wings are equally membranous and diaphanous with the hind wings and of much the same general size, while in most of their later descendants in the groups specified the front wings are generally smaller than the hind wings and have a more or less definitely coriaceous structure or have the veins much thicker and more approximated than in the hind wings.

In this survey, however, we have made no mention of the Coleoptera or of the Metabola. As to the latter, we note that the front wings are invariably diaphanous like the hind wings (when these exist), and that the veins of the front pair are neither abundant nor noticeably stout. In short they retain the characteristics of the front wings of Paleozoic insects more than do any of the Heterometabola, unless we except, in certain points, the Neuroptera, many of which are equally or even better comparable. It seems therefore highly probable that the Metabola and the Neuroptera sprang together from the allied families of Palæodictyoptera whose obscure common relation to the Pseudoneuroptera and Neuroptera proper has been referred to above.

When we come to the Coleoptera the case is different. None have been found in Paleozoic rocks,[1] though they occur with fully developed characteristic elytra in the very earliest Mesozoic deposits, as the Rhactic and even the Trias. Nor do we find anything in the least degree allied to the elytral structure among any of the Paleozoic insect types. But we do find traces of borings in wood similar to those made by Coleoptera to-day, and it is not unreasonable to suppose that all the Paleozoic ancestors of Coleoptera were wood-borers throughout life (a habit to which the ample Carboniferous forests would certainly have afforded full play), and that their absence from the rocks is due to this secretive habit. Certainly the gradual assumption of elytra for membranous front wings would be particularly favorable to a creature living in hard-walled burrows, where membranous wings would suffer abrasion; and, although this is an almost purely hypothetical assumption, we have a certain warrant for it in the probability that Coleoptera, like the other orders, had purely Palæodictyopteran ancestors in Paleozoic deposits and in three facts: (1) the absence of coleopterous remains in Paleozoic rocks, (2) their presence in Triassic and Rhaetic deposits, and (3) the occurrence in Carboniferous trees of borings similar to those now made by beetles in like places.

[1] Long after this manuscript was sent to Germany I learned, through letters from E. Dathe to Hauchecorne (Zeitschr. der deutschen geol. Gesellsch., 1885, 542) and to Dr. Zittel, that the Silesian culm of Steinkunzendorf had furnished five beetle remains, of which four are elytra and one a specimen showing elytra and pronotum. The largest elytron is said to be 18 millimeters long and 14 millimeters broad, the smallest 8 millimeters long and 6 millimeters broad (the breadth probably including a pair of elytra). One specimen examined by Dr. F. Karsch, of Berlin, was taken by him to be the elytron of a carabid or of a tenebrionid. Further details of this find will be awaited with interest.

We may then draw the following picture of the probable sequence of events in the geological history of insects and of the peculiarities of the different epochs—a picture which does not carry us back to any apterous condition of hexapods, the only speculations on this subject drawn from existing biological data (however probable they may be or however unanimously such views may be held by those who have speculated on the subject) being altogether unsupported by a scintilla of paleontological evidence.

The earliest insects, then, were generalized hexapods, Palæodictyoptera, in which the four wings were equally and similarly developed, membranous, and with very simple neuration. Their metamorphoses were simple and "incomplete," the young leaving the egg with the form of the parent but without wings, the assumption of which required no quiescent stage before maturity. They appeared probably as early as any land-plants, certainly by the middle of the Silurian epoch, and continued as a homogeneous type until the end of the Paleozoic period. Certain indications of differentiation were present, but they were largely those which characterize in later times simple families or limited groups of families, such as an excessively long and slender body (Protophasmida) or an anal area separated from the rest of the wing (the front wing only) by a deep furrow (Palæoblattariæ), but in some cases foreshadowing ordinal distinctions, as in the thickening of the basal portion of the front wing (Phthanocoris). Probably also a life-long burrowing habit of some wood-feeding forms had induced in them an incipient hardening of the front wing in preparation for a greater change that awaited them. Most of these Paleozoic forms were of large size, with bulky bodies and ample wings. In repose they rested their wings by overlapping on their abdomen, a habit which very few of their descendants have altogether overcome (butterflies, most dragon flies).

With the advent of Mesozoic times came the greatest changes which the insect world has seen. Nearly all along the line there was developed a differentiation of the front and hind wings, the latter growing relatively larger, with a special expansion of the anal area, the former changing its membranous, diaphanous character for one more or less pergamentous or corneous, or approximating this condition by a multiplication or an increase in the size of the nervures, while special structural features were assumed by each particular type, as for instance in the cockroaches, where by the amalgamation or altered direction of certain veins of the front wings they became still further changed in character from the hind pair. Thus in the same Triassic deposits we find side by side several species of cockroaches which, examined together, bridge over the distinctions between the ancient Palæoblattariæ and the modern Blattariæ: First, those in which the front wings are diaphanous, with distinct mediastinal and scapular veins, and the anal nervures impinge on the border of the wing; next, those having a little opacity of the front wings, with blended

mediastinal and scapular, and the anal veins as before; then those with still greater opacity, with the same features; and finally those having the structure of the front wings coriaceous or leathery, with blended mediastinal and scapular veins and anal nervures impinging on the anal furrow. By such steps as these were the undifferentiated Palæodictyoptera transformed into the modern types of Orthoptera, Neuroptera, Hemiptera, and Coleoptera. It is probable that these orders were first differentiated, and later the Metabola, for in the Trias and Rhaetic we find only the Heterometabola, and not yet all of them. Still, looked at in a broad way, we may say that all the existing orders of insects originated early in Mesozoic times, for the Diptera and Hymenoptera appear in scanty numbers in the Lias and the Lepidoptera in the Oölite. The Metabola, however, are nowhere abundant in the Mesozoic period and are always subordinate to the Heterometabola, though as soon as the Tertiary period opens they assume a preponderating part, which was probably even greater than appears, since the readier preservation of Coleoptera in rock deposits undoubtedly gives them a better relative standing in our knowledge of the past than is really their due. We may then state in broad terms that, as far as insects were concerned, the Paleozoic epoch was the age of Palæodictyoptera and especially of cockroaches (since nearly half the known species belong to that group), that the Mesozoic epoch was the age of Heterometabola, the Cenozoic of Metabola and Coleoptera, while the present is the age of Coleoptera and Metabola, the relative proportion of Coleoptera to the other orders having steadily increased from the close of the Paleozoic epoch.

The "complete" metamorphosis of the higher (and of a few lower) insects is now generally looked upon as a secondary adaptive feature, originating from an "incomplete" metamorphosis, the very existence of which among so many, and these exclusively the lower insects, is an argument in favor of such a view. That these more complex metamorphoses originated simultaneously with the segregation of the existing orders of insects is rendered probable from the similarity of larval form and structure in different orders, as the maggot-like larvæ of Musca, Vespa, and Curculio, for instance, as well as from the existence of very different types of larvæ within the same order, as, for example, Stratiomys and Œstrus, Tenthredo and Bombus, Dytiscus and Calandra. The striking hypermetamorphosis of some Meloidæ, not shared by neighboring families of Coleoptera, gives plain proof of the amount of change which may be acquired within narrow limits and in comparatively brief time. There is no good evidence that the Meloidæ were differentiated before the Tertiaries, yet Menge has found in the amber deposits of the Oligocene what are apparently the larvæ of Meloidæ in the triungulin stage. It may be stated in general terms that, although comparatively little is known of the earlier stages of extinct insects, all our knowledge tends to show that the present general conditions of metamorphosis existed at least

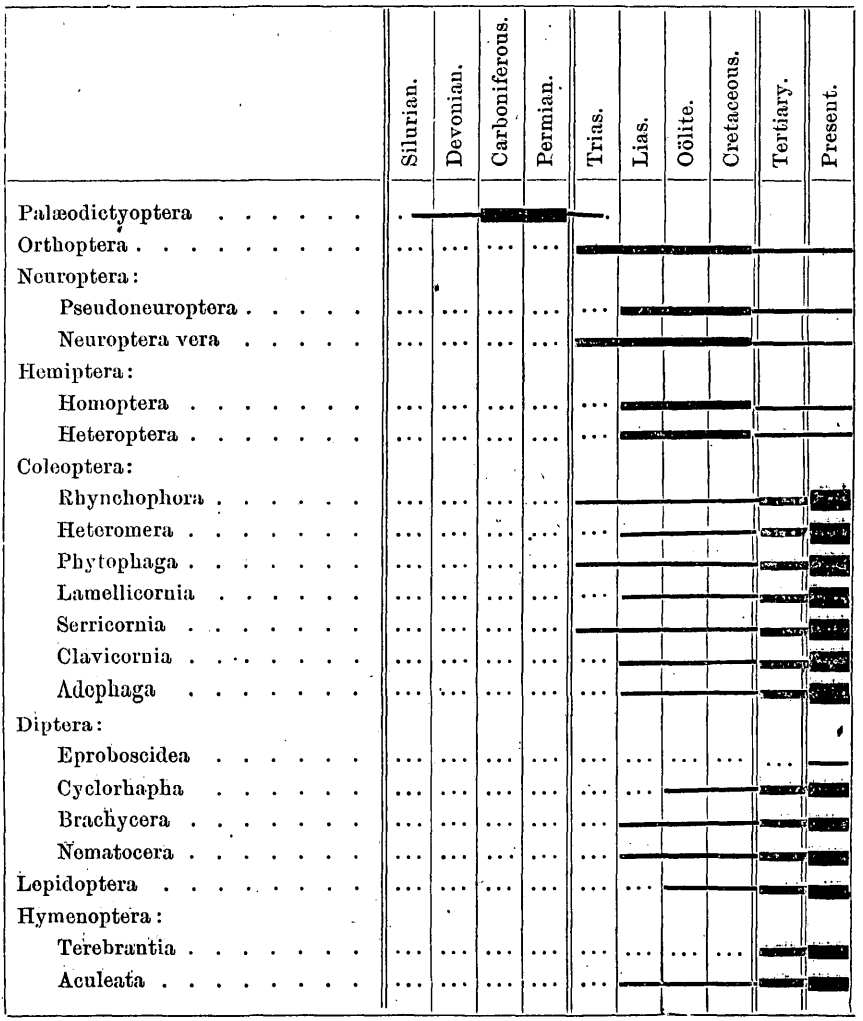
as far back as the middle or latter part of the Mesozoic period. The larvæ of the Oligocene (of which we know most) had all the characteristics of those of the present day, and of the few from the Mesozoic rocks the the same may be said, with the possible exception of the oldest known larva, *Mormolucoides articulatus*, from the Trias of New England, which is of a somewhat anomalous character, though probably a sialid. From the Paleozoic rocks no larvæ whatever are known, whether of the "complete" or "incomplete" type.

The sexes, as is well known, are now completely distinct in insects. Certain peculiarities of secondary sexual dimorphism accompanying special forms of communistic life, such as the "neuters" and "workers" in Hymenoptera and the "soldiers" among the Termitina, are also found, as would be expected, among the fossils, at least through the whole series of the Tertiaries. The same may be said of other sexual characteristics, such as the stridulating organs of the Orthoptera, and of peculiarities of oviposition, as seen in the huge egg capsules of an extinct sialid of the early Tertiaries. The viviparity of the ancient Aphides is suggested, according to Buckton, by the appearance of one of the specimens from the Oligocene of Florissant, while some of the more extraordinary forms of parasitism are indicated at a time equally remote by the occurrence in amber of the triungulin larva of Meloe, already alluded to, and of a characteristic strepsipterous insect; not only too are the present tribes of gall-making insects abundant in the Tertiaries, but their galls as well have been found.

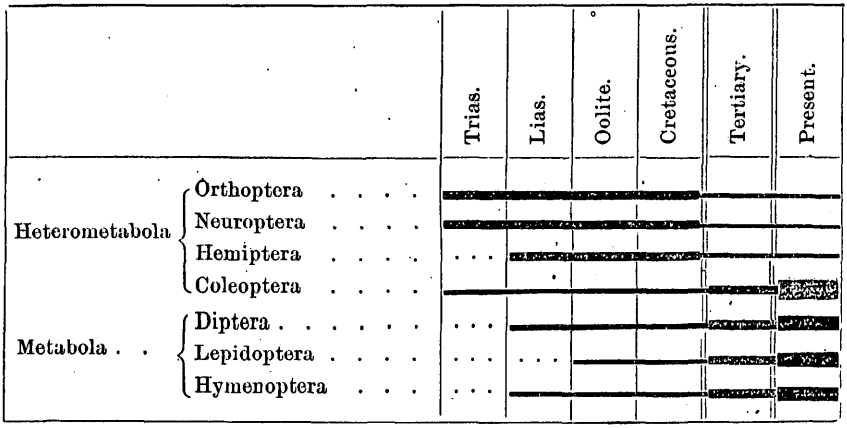
In fact, by the presence in the rocks of nearly every group in which interesting special biological phenomena have been found in present times, we are forced to believe it highly probable that the general features of insect life, with all their varied dependence upon their environment, have remained almost without change through at least the Tertiary epoch. In keeping with this is the fact, not too much to be relied upon, that the larger proportion of Tertiary insects, and no small number of Mesozoic types as well, have been referred to existing genera. This may be due in part to their incomplete preservation or to their insufficient study, and it is highly probable that one or the other of these causes may account for most of the cases which are known from the Mesozoic deposits. But these explanations will not fully suffice for the Tertiary deposits, since we can test the matter to a certain extent in the excellent relics of the amber, at least in the groups which have been carefully studied. Here we find that, as a general rule, only from a fourth to a third of the genera are extinct, and these genera are usually those which are least prolific. Of the twenty-three genera of Formicidæ, carefully studied by Mayr, only six (with seven species out of forty-nine) are looked upon as extinct; and of the Psocina, studied by Hagen and Kolbe, three out of the ten genera (five species out of fifteen) are in the same category.

The following table shows in a condensed form the geological distribution of the orders and larger divisions of fossil insects. The weight of the lines indicates in a very general way the comparative development and importance of the type.

Geological distribution of insects.



Or, if we present the same facts for the existing orders simply, the sequences insisted upon above will be more clearly seen, as in the following table:



COMPARATIVE HISTORIES OF MYRIAPODA, ARACHNIDA, AND HEXAPODA.

In conclusion we may note the contrasts which the geological histories of the Myriapoda, Arachnida, and Hexapoda present when compared.

In the Arachnida four orders existed side by side in Paleozoic times, the most abundant of them disappearing at its close; the other three have continued to the present time and appear to have been as widely separated from each other at that distant period as now, and only one of them has since received a preponderating development. In addition to this, three new orders make their appearance in Tertiary times, but, two of them being the very lowest of their class, their apparent absence from Mesozoic deposits is probably due to the "imperfection of the geological record," and it is not improbable that all of these may prove to be the differentiated descendants of Anthracomarti, the order peculiar to the Paleozoic era.

In the Myriapoda we find two very diverse orders existing in Paleozoic times, which disappeared with that epoch and were replaced in later times by two others equally and to some extent similarly distinct from each other and from those which preceded them. It is probable that they are the descendants of the early types and that a fifth order, at present only known in recent times, was also derived from one of them.

In the Hexapoda, all known Paleozoic forms are referable to a single order, which disappeared at or shortly after the close of that era, being replaced in the Mesozoic epoch, through differentiation, by the seven existing orders.

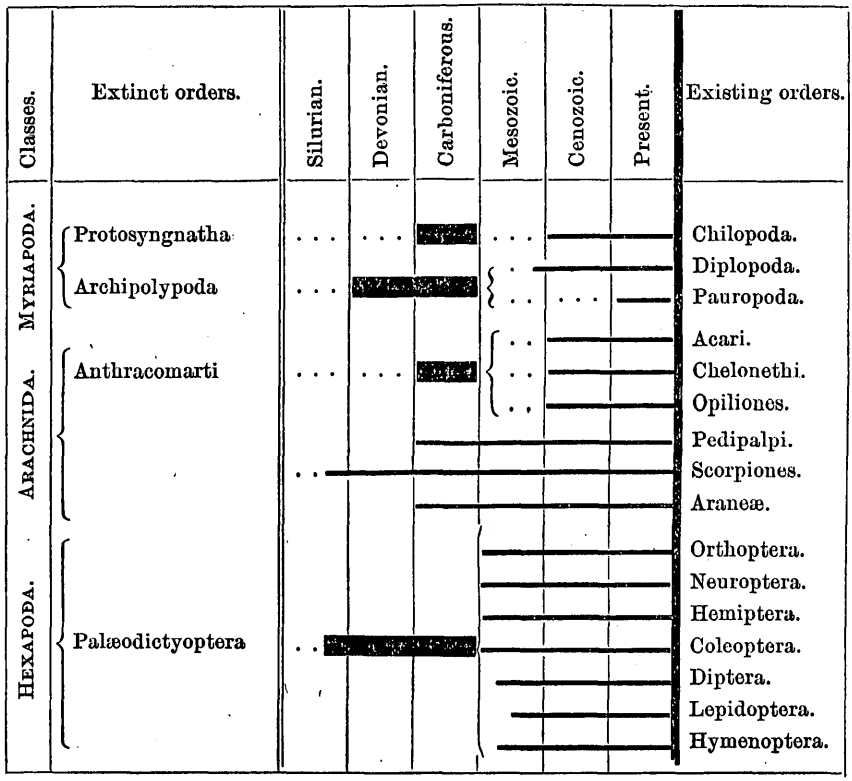
We thus find that in the Paleozoic epoch we have in the Arachnida one extinct and three existing orders; in the Myriapoda two extinct orders and none of the existing; in the Hexapoda one extinct order and no existing ones, all of these being afterwards differentiated from the common Paleozoic stock.

In passing backward, then, we reach a common ancestral stock for the Hexapoda as soon as the close of the Paleozoic epoch, and we continue to retain the same as far back as the Middle Silurian. In the Myriapoda we lose all trace of the existing orders when we reach Paleozoic times, but find them replaced by others as widely differentiated from each other as existing types among themselves, and one of these types we trace back to the Middle Devonian. In the Arachnida one half of the existing orders may probably be traced to a Paleozoic type since extinct, while the other half occur side by side with this extinct type and one of them is found as far back as the Upper Silurian.

Notwithstanding, then, that winged insects are at present known from older rocks than any containing either Arachnids or Myriapods, it would seem highly probable that the ancestral stock of these last will yet be found in older deposits than will the true insects. The relationship of the Arachnida to the Merostomata and the probability that some of the early Myriapoda were amphibious render it further probable that the ancestral stocks of Arachnida and Myriapoda were of aquatic habit, while it is evident that the ancestral winged Hexapoda must have been, at least in adult life, terrestrial. Their apparition would not therefore be expected to antedate that of land plants.

The following table, in which the heavy lines are meant to indicate the chronological range of the presumed ancestral and extinct stocks, while the lighter lines show that of the existing orders, will illustrate these statements graphically. The purely hypothetical portions are given in dotted lines.

Chronological range of presumed ancestral and extinct stocks.



INDEX OF NAMES.

[Groups higher than genera are printed in italics.]

F.

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ADVERTISEMENT.

[Bulletin No. 32.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is specially supplied to this Office by the Secretary of the Interior, the Survey has no copies of any of its publications for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

The Sixth Annual Report is in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, and IX are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price, $1.15.

ADVERTISEMENT.

The following are in press, viz:

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 237 pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl.

XII. Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

— Lake Bonneville, by G. K. Gilbert.

— Sauropoda, by Prof. O. C. Marsh.

— Stegosauria, by Prof. O. C. Marsh.

— Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker.

— The Penokee-Gogebic Iron-Bearing Series of North Wisconsin and Michigan, by Roland D. Irving.

— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.

— Younger Mesozoic Flora of Virginia, by William M. Fontaine.

— Report on the Denver Coal Basin, by Samuel F. Emmons.

— Report on Ten-Mile Mining District, Colorado, by Samuel F. Emmons.

— Report on Silver Cliff Mining District, by Samuel F. Emmons.

— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient sizes. To facilitate this, each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 30 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

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TO THE DIRECTOR OF THE
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WASHINGTON, D. C.

WASHINGTON, D. C., *September* 1, 1886.